An exploration of Closing-in behaviour in dementia, development and healthy adulthood

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DECLARATION

I declare that this thesis is my own composition, and that the material contained in it describes my own work. It has not been submitted for any other degree or professional qualification. All quotations have been distinguished by quotation marks and the sources of information acknowledged.

Elisabetta Ambron

15/02/2010

Dedicated to Clotins,

who showed me closing-in behaviour for the first time. Miss you.

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…and here is my story…

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Abstract

Closing-in Behaviour (CIB) is the tendency observed in copying tasks, both graphic and gestural, in which the copy is made inappropriately close to or on top of the model. It is classically considered as a manifestation of Constructional Apraxia (CA) and it is often observed in patients with dementia. CIB is not only a symptom of pathology, but it is also observed in children's first attempts at graphic copying. However, CIB shows an inverse pattern in development and dementia: while its frequency increases in severe dementia, CIB progressively decreases with development. The cognitive origins of CIB are still unclear. Two main interpretations dominate CIB literature: the compensation and the attraction hypotheses. The first hypothesis interprets CIB as a strategy specific to copying tasks that the patient adopts to overcome visuospatial and working memory deficits. In contrast, the attraction hypothesis considers CIB as a primitive behaviour, not specific to copying, and characterized by the default tendency to perform an action toward the focus of attention. This thesis aimed to study the characteristics and the cognitive origins of CIB in dementia, development and healthy adulthood. It has three main sections. The first and second sections explore CIB in patients (with Alzheimer's disease- AD and Frontotemporal dementia) and in pre-school children, using survey and experimental studies, to investigate if CIB might have common characteristics and cognitive substrates in these different populations. The results provided converging evidence for the similar nature of CIB in development and dementia. For instance, survey studies in patients with dementia (Chapter 3) and preschool children (Chapter 6) showed that performance in attentional tasks predicted the appearance of CIB. In a similar vein, experimental studies showed support for the attraction hypothesis of CIB in a single patient with AD (Chapter 4) and pre-school children (Chapter 7 and 8). These results were not, however, replicated in a larger cohort of patients with AD due to practical reasons (Chapter 5). The last section was devoted to modelling CIB in normal participants, using complex graphic copying (Chapter 9) and dual task paradigms (Chapter 10). The results showed further support for the attraction hypothesis of CIB and underlined the difficulties of eliciting this default bias in normal adults. To conclude, this thesis radically changes the classical consideration

of CIB as a manifestation of CA and demonstrates that CIB is a general default tendency, not specific to copying tasks. This work indicates avenues for new studies, which might consider the possible expression and consequences of this behaviour in patients' daily lives.

Sinopsi

Closing-in Behaviour (CIB) e' la tendenza che si osserva in compiti di copia, di disegno e gestuali, in cui la copia e' posta in modo inappropiato vicino o sul modello da copiare. Tale fenomeno e' stato considerato come una manifestazione dell'Aprassia Costruttiva (AC) ed e' spesso osservato in pazienti con demenza. Il CIB non e' soltanto un sintomo rilevato in presenza di patologie ma e' anche osservato nei primi approcci dei bambini ai compiti di copia. Il CIB presenta caratteristiche opposte nello sviluppo e nella demenza: mentre la frequenza del CIB aumenta in demenza avanzata, esso diminuisce progressivamente con lo sviluppo. Le origini del CIB sono ancora non chiare. Due maggiori interpretazioni hanno dominato la letteratura del CIB: l'ipotesi della compensazione e l'ipotesi dell'attrazione. La prima ipotesi considera il CIB come una strategia compensatoria, specifica di compiti di copia, che il paziente adotta per compensare deficit delle funzioni visuospaziali e della memoria di lavoro; al contrario, l'ipotesi dell'attrazione considera il CIB come un comportamento primitivo, non specifico di compiti di copia, e caratterizzato dalla tendenza automatica ad eseguire un'azione verso il focus attentivo. Questa tesi ha come obiettivo lo studio delle caratteristiche e delle origini cognitive del CIB nella demenza, nello sviluppo e nell'eta' adulta. Ha tree maggiori sezioni Nella prima e nella seconda sezione, il CIB viene esaminato in pazienti con malattia di Alzheimer (MA) e con demenza fronto-temporale, e in bambini di eta' prescolare, attraverso studi sondaggio e sperimentali, al fine di indagare se il CIB ha caratteristiche e substrato cognitivo simili in queste differenti popolazioni. I risultati forniscono evidenze convergenti riguardo una simile natura del CIB nello sviluppo e nella demenza. Per esempio, gli studi sondaggio in pazienti con demenza (Capitolo 3) e in bambini di eta' prescolare (Capitolo 6) hanno dimostrato che la performance in compiti attentivi predice la presenza del CIB. Allo stesso modo, gli studi sperimentali hanno supportato l'ipotesi dell'attrazione in un caso singolo con MA

(Capitolo 4) e in bambini di eta' prescolare (Capitolo 7 e 8). Tali risultati non sono stati, tuttavia, replicati in un ampio cohort di pazienti con MA, per ragioni pratiche (Capitolo 5). L'ultima sezione e' stata devoluta a modellare il CIB in adulti normali, usando compi di copia complessi (Capitolo 9) e paradigmi di dual task (Capitolo 10). I risultati hanno mostrato ulteriori evidenze per l'ipotesi dell'attrazione e messo in luce le difficolta' nell' elicitare questo bias in adulti normali. Per concludere, questa tesi cambia la classica interpretazione del CIB, concepito come una manifestazione dell'aprassia costruttiva e dimostra che il CIB e' una tendenza generale, non specifica di compiti di copia. Questo lavoro ha aperto la strada per nuovi studi, che potrebbero considerare la possibile espressione e le consequenze di questo fenomeno nella vita quotidiana dei pazienti.

List of abbreviations

ACE: Addenbrooke's Cognitive Examination

AD: Alzheimer's disease

ANOVA: Analysis of the Variance

BVA: Battery for Visuospatial Abilities

CA: Constructional Apraxia

CIB: Closing-in Behaviour

CS: Constructional skills

FAB: Frontal Assessment Battery

FTD: Frontotemporal dementia

LBD: Left brain damage

MMSE: Mini Mental State Examination

MODA: Milan Overall Dementia Assessment

RBD: Right brain damage

RT: Reaction time

SART: Sustained Attention Response Task

SD: Standard deviation

VaD: Vascular Dementia

CHAPTER 1
Constructional Apraxia

The impairment of drawing and building as consequence of brain damage is known as Constructional Apraxia (CA). The first observations of constructional problems date back to 1909 (Rieger, 1909), however, it was in 1934 that Kleist coined the term CA and attempted to provide a systematic classification of this syndrome. Kleist (1934) defined CA as a disorder of action, which concerned a specific impairment in drawing, assembling, and building tasks, in conjunction with preserved visuoperceptual or motor planning abilities. However, in modern practice, CA operates as a broad clinical label for any impairment of drawing or building performance.

CA can derive from an impairment of a variety of cognitive functions and lesions in a number of different areas of the brain can cause CA (Papagno, 2003). Despite Kleist's observations (1934), CA can derive from impairments in visuoperceptual abilities, mental representation, and motor abilities. Therefore, this syndrome can appear as an expression of a specific cognitive deficit, but also as a symptom of more general cognitive deterioration, which implies the interaction of several cognitive deficits. Indeed, a pure CA syndrome, which is not the secondary symptom of receptive or executive deficits, is rarely observed (Trojano & Grossi, 1998). Consequently, CA is not a unitary syndrome caused by a specific brain damage (Guérin, Ska & Belleville, 1999), but a multicompontent condition which appears as a consequence of various cognitive deficits.

The multicomponent nature of CA is directly associated with the task used to assess this syndrome. "Constructional tasks", such as drawing or building performance, are complex tasks, requiring different cognitive abilities, therefore sensitive to different cognitive impairments. Moreover, patients with different cognitive impairments may show a similar performance in constructional tasks and a single constructional error can be the expression of a variety of cognitive deficits. For these reasons, in the study of CA, there is a constant tension between the necessity to generalise results and establish general rules in the assessment of CA, and the essential exploration of the qualitative aspects of a single drawing performance in order to derive the cognitive basis of CA in a specific patient or group of study (Smith & Gilchrist, 2005).

Taking together these considerations, the variety of methods used to assess CA and the consequent heterogeneity of the results observed in the study of this syndrome are not surprising. The present review aims to discuss the literature of CA, without the pretension of being exhaustive, but with the intention of discussing the critical issues in the study of this syndrome. First, the tasks used to assess CA will be described, showing different types of assessment and methodological approaches in the study of CA. Second, the effect of the variety of approaches in the assessment of CA in brain-damaged patients will be explored. Third, three cognitive models proposed to explain the cognitive processes involved in a specific constructional task (graphic copying) will be introduced. Finally, an even more specific, symptom-targeted approach will be proposed as the basis for the present thesis.

CONSTRUCTIONAL TASKS AND SCORING PROCEDURES

Constructional tasks assess the ability of the subject to correctly reproduce a shape, an object, or a pattern, either from memory or under the visual guidance of a model (Table 1.1). This last group of tasks can require either drawing, or assembling three dimensional structures (e.g. blocks or matches).

Drawing tasks require drawing a shape from memory. In spontaneous drawing, the patient is asked to draw a named object (Warrington, James, & Kinsbourne, 1966; Kirk & Kertez, 1989), without the visual presentation of the shape to be copied. One of the most common spontaneous drawing from memory tasks is the Clock drawing test. The patient is asked to draw the face of the clock and to set the time at a certain hour (e.g. ten past eleven; two forty-five; ten past five) (Goodgrass & Kaplan, 1982; Mathuranath, Nestor, Berrios, Rakowicz, & Hodges, 2000; Sunderland et al., 1989). The comprehension of the time set proposition is a specific requirement of this task in order to perform an accurate drawing (Libon, Swenson, Barnoski, & Sands, 1993). Therefore, as for other constructional tasks, deficits in this task might depend upon semantic-lexical deficits (Gainotti, Silveri, Villa, & Caltagirone, 1983) rather than visuo-constructional deficits. This task can also be used in a copying version, asking the patient to copy the picture of a clock (Goodgrass & Kaplan, 1982).

Table 1.1. Constructional Tasks

	Drawing		**Copying**	
Typology	Spontaneous	From memory	Graphic	Construction
Task requirement	To draw a shape	To draw a shape briefly shown or after a delay	To copy drawing a shape	To copy drawing a shape
Model presented	No	Yes (but then removed)	Yes	Yes
Most commonly used tasks/stimuli	House, clock, bicycle Clock test	Rey-Osterrieth Complex Figure	Rey- Osterrieth Neker's Cube Benton visual retention tests	Block's test (WAIS)
Type of stimuli	Objects or Geometrical shapes	Objects or Geometrical shapes	Objects or Geometrical shapes	Pattern or Geometrical shapes (tower, cross, pyramid)
Tools	Paper and pencil	Paper and pencil	Paper and pencil	Blocks (single or multiple coloured sides), sticks, matches

In drawing from memory tasks, the model can be briefly presented and then removed, and the patient is asked to perform the copy immediately, or after a certain delay. Therefore, to correctly perform the task, the appropriate visuospatial image of the object or shape must be recalled from memory (Libon et al., 1993). This kind of task informs the examiner about constructional skills related to the ability to perform an accurate drawing. These skills involve placing the elements in the correct spatial relationships, however constructional performance is also influenced by memory, planning, lexical, semantic and imaginative abilities (Trojano & Grossi, 1994).

Copying tasks assess the ability to accurately reproduce a visually presented model, by drawing or assembling three-dimensional (3D) structures. Graphic copying tasks are the most common constructional tasks used in clinical practice (Benton & Fogel, 1962). These tasks require copying of abstract geometric shapes or of objects. The model can be presented on the same sheet of paper, often on the top half of the page (Spinnler & Tognoni, 1987), or on a separate sheet from the copy (Carlesimo et al., 1993). Graphic copying tasks can vary in complexity, from simple bidimensional shapes (triangle square or diamond) to more complex (e.g. Rey figure) or three dimensional depictions (e.g. Necker's Cube). Complex constructional tasks, such as Rey-Osterrieth Complex Figure (Rey, 1941; Osterrieth, 1944), assess constructional skills, but also require high levels of executive control to plan and organize the copying drawing, and the use of a specific copying strategy to execute the task.

The 3D constructional tasks require assembling 3D structures from elements such as sticks, matches, or blocks following a presented pattern. One of the most common assembling tasks is the block design (Wechsler, 1939). The patient is presented with blocks, with two red and two white faces, and two half -red and half-white faces divided by a diagonal. The patient is asked to reproduce constructions made by the examiner or a presented pattern and the performance is timed.

A different version of block construction has been proposed by Benton and Foger (1962). In their task, the patient is asked to reproduce 3D models of increasing complexity and number of elements, using monochrome blocks of different sizes. The model can be either pre-assembled (Benton & Fogel, 1962) or assembled directly in front of the patient (Arrigoni & De Renzi, 1964), with the latter providing the patient with the advantage of a plan for graphic copying. This task has proven not to be strongly related to performance in graphic copying, supporting the view that CA is not a unitary concept (Benton & Foger, 1962).

The different constructional tasks involve similar cognitive abilities and require the assembling of different units in order to form an unitary figure (Benton & Fogel, 1962), but differ in the load on memory, visuospatial abilities, and the requirement or not of a graphomotor response (Papagno, 2002). For example, the copy of models using 3 dimensional elements (matches or blocks) involves similar cognitive abilities to drawing and graphic copying, but it has the advantage of a lower requirement for auditory comprehension and long term memory as compared to drawing on command tasks (Libon et al., 1993) and allows the assessment of constructional abilities bypassing the motor-graphic component of graphic copying tasks.

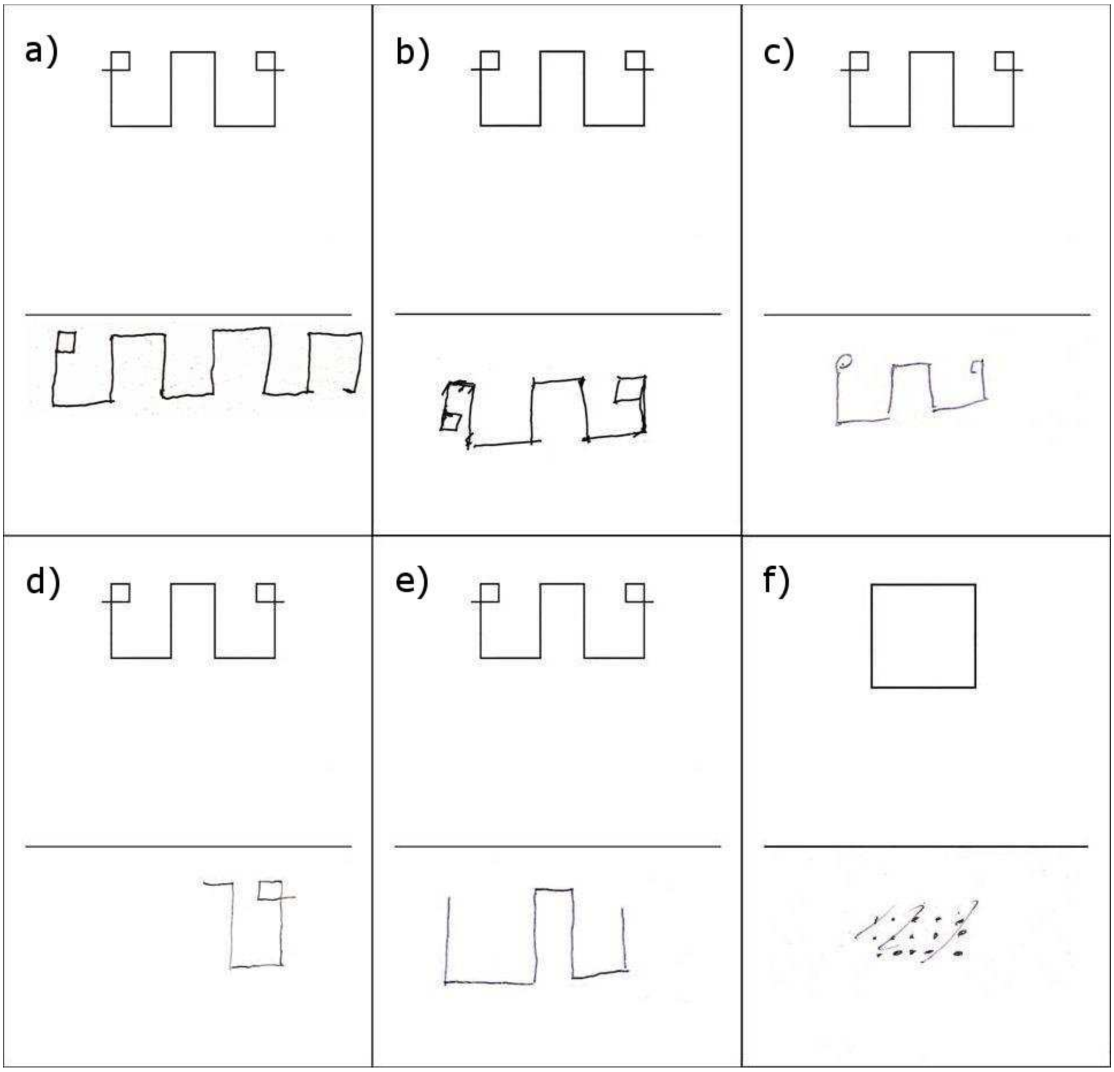
Different degrees of performance can be observed not only between constructional tasks, but also within a specific constructional type of task, such as copying. Hécaen and Assal (1970), for example, showed that patients with left brain-damaged (LBD) had major difficulties copying the shape of a cube. Their performance improved when they copied the figure of a house or of a bicycle. On the contrary, patients with right brain-damaged (RBD) showed poor performance in the bicycle graphic copying task, while their performance was better in copying the shape of a cube or a house.

Due to the different cognitive abilities involved in drawing from memory or graphic copying, the dominant trend in the study of CA has been to focus on one specific type of constructional task, such as copying (Papagno, 2002). However, the ambiguity in CA definition is directly reflected in the difficulty of assessing CA in graphic copying. The debate between considering CA as a unitary syndrome or as an umbrella term for a variety of different impairments is mirrored in the methodological procedures used to assess this syndrome. The studies of CA in graphic copying have been characterized by a constant tension between the assessments of the copy production as a whole, based upon the evaluation of accuracy of the graphic copy, and the analysis of different sub-types of constructional errors.

The accuracy of the copy is often assessed using scales based on the resemblance between the model and the copy, which range from 0 (the model is unrecognizable) up to a maximum score (the model is recognizable) of 2 (Spinnler & Tognoni, 1987) or 4 (Carlesimo et al., 1993), depending on the degree of differentiation of the different scoring categories. Although a numerical score may be assigned, such scales are rather qualitative, and the assessment of accuracy is based on the judgement of the examiner. Therefore, the experience, personal characteristics, and expectations of the examiner might bias the assessment of the drawing accuracy. For this reason, in research settings, the assessment of the accuracy is often carried out by naive examiners and the inter-rater reliability is used to validate the scoring procedure. However, short accuracy scales might not allow a reflection of all the differences between drawing performances. Moreover, accuracy of the copy is influenced by the overall appearance of the drawing, as well as by specific errors, which may or may not be directly related to CA. For example, a patient with hemispatial neglect might either omit the left part of the drawing or the whole picture once presented in the left part of the paper. In this case, the accuracy of the graphic copy would be estimated as quite low, although the CA would be just a secondary symptom of hemispatial neglect. For this reason, in conjunction with accuracy, the presence of specific constructional errors is often assessed. Such scoring procedures give the examiner a greater range of options to classify the copy, but may be even more sensitive to personal judgment, because of the subtle boundaries between the different scoring categories. Moreover, scoring schemes, which aim to incorporate qualitative and quantitative aspects of drawings (Kirk & Kertesz, 1993) or anticipate all possible outcomes (Gainotti & Tiacci, 1970), are difficult to apply in practice and risk over fractionating the drawing performance, leading up to loss of essential information about the drawing production as a whole.

Several types of constructional errors can characterize a graphic copy (see Figure 1), such as perseverations (the whole shape or lines of the shape were duplicated), spatial alterations (elements of the model are reproduced in an incorrect spatial relationship), simplifications (the copy is a simplified version of the model), omissions (some part of the original model are not reproduced), scrawl (original model is not recognizable), and closing-in behaviour (part of the original model is used for the copy) (see Grossi, Calise, Correra, & Trojano, 1996). The definitions of specific CA error are, however, quite broad and in clinical practice it is often difficult to distinguish a specific constructional error. Moreover, two or more errors might appear in conjunction in the same drawing, causing a difficulty in both judging the accuracy of the graphic copy and in classifying the copy performance with a unique error label. For example, in Figure1.1a, although the main constructional error is the perseveration of the central unit of the model, some elements are also omitted. Therefore, as for accuracy, the correct observation of a CA error might depend upon the level of experience and the personal judgement of the examiner. Moreover, the simple assessment of the presence of a constructional error without considering the severity of this manifestation might cause the loss of important information, flattening differences between drawing productions. For example, a patient might perseverate in different ways: retracing his own graphic copying, reproducing one or more elements of the model several times, reproducing the whole model more than once, or drawing a shape previously produced in earlier tasks. These different performances might all be classified as 'perseveration', but they could also be manifestations of different cognitive deficits.

Figure 1.1. Examples of (a) perseverations, (b) spatial alteration, (c) simplifications; (d) neglect; (e) omissions, (f) scrawl



Taken together, these observations show that there is a trade off between qualitative and quantitative assessment of CA. Qualitative assessments of drawing performance are sensitive to subjective bias, and the use of such schemes in a research setting is often problematic. The need to establish formal and replicable assessment of CA led to the development of some systematic quantitative measures, which aimed to quantify drawing performance (Smith & Gilchrist, 2005). However, this approach tends to be very narrowly specific to a particular task and risks the loss of important information about the qualitative aspects of the drawing, which is essential in order to understand the cognitive origins of the drawing alteration. This constant tension between qualitative and quantitative assessment is an unresolved dilemma. For this reason, it is not surprising that the literature on CA is characterized by heterogeneity of results regarding the relationship between CA and brain lesions or forms of dementia.

CONSTRUCTIONAL APRAXIA: A SYMPTOM OF FOCAL BRAIN LESIONS

Kleist (1934) originally observed CA after damage to the left hemisphere, and the assumption of a relationship between CA and the left hemisphere dominated the study of CA for a decade (Guérin et al., 1999). However, subsequent studies did not confirm the specific involvement of the left hemisphere. On the contrary, two complementary hypotheses developed: the dominance of the right hemisphere in visuo-constructional abilities and a different nature of CA in RBD and LBD patients. Table 1.2 reports a series of studies conducted to assess CA in RBD and LBD patients. The studies reported are not a comprehensive account of the literature on this topic but aim to illustrate the range of methods used to assess differential hemispheric involvement in CA.

Table 1.2. Summary of studies on CA in patients with focal brain lesions

Authors	Task	Sample	CA frequencies (accuracy)	CA Errors	Relationship CA- cognitive Deficits
Piercy, Hécaen and de Ajuriaguerra, 1960	- graphic copying, - constructions, - spontaneous drawing	215 LBD 118 RBD	25 (12%) LBD; 42 (22%) RBD; **[RBD >LBD]**	LBD: omission RBD: spatial distortions	
Costa and Vaughan, 1962	- Construction	18 RBD 18 LBD 18 controls (patients without BD)	6 (33%) LBD 10 (55%) RBD 6 (33%) controls **[RBD =LBD]**		Significant correlation CA and performance in visuo-peceptual task (Raven Test) in RBD, but not in LBD
Piercy and Smyth, 1962	- graphic copying, - constructions, - spontaneous drawing	18 LBD 19 RBD (both groups: parietal lesions)	7 (39%)LBD 13 (68%) RBD **[RBD >LBD]**		Significant correlation CA and performance in visuo-peceptual in patients with parietal lesions
Warrington et al., 1966	- graphic copying, - spontaneous drawing	31 LBD 31 RBD	17 (55%) LBD 19 (61%) RBD **[RBD =LBD]**	LBD: simplifications RBD: spatial distortion	
Arrigoni and De Renzi, 1964	- graphic copying, - constructions	70 LBD 55 RBD	13 (19%)LBD 21 (38%) RBD **[RBD >LBD]**		
Hécaen and Assal, 1970	- graphic copying - graphic copying with landmarks - constructions, - spontaneous drawing	14 LBD 18 RBD	No significant difference between RBD and LBD in the overall accuracy score	LBD increase in performance with the help of landmarks RBS stable performance with or without landmarks	

Authors	Task	Sample	CA frequencies (accuracy)	CA Errors	Relationship CA- cognitive Deficits
Gainotti and Tiacci, 1970		100 LBD 100 RBD		LBD: simplifications, difficulties in reproductions of angles RBD: spatial distortion, additions, neglect	
Arena and Gainotti, 1978;	- graphic copying,	43 LBD 30 RBD	16 (37%) LBD 11 (37%) RBD **[RBD =LBD]**		No significant difference between RBD and LBD in perceptual abilities (Visual Retention Test)
Gainotti, D'Erme and Diodato, 1985	- graphic copying,	118 LBD 95 RBD	25 (21%) LBD 31 (33%) RBD **[RBD =LBD]**	Same frequency of simplifications, omissions, spatial distortion; RBD higher frequency of neglect errors	
Villa, Gainotti, and De Bonis, 1986	- graphic copying, - graphic copying with landmarks	114 LBD 71 RBD	33 (39%) LBD 27 (32%) RBD **[RBD =LBD]**	RBD increase in performance with the help of landmarks	
Griffiths and Cook, 1986;	- graphic copying,	11 LBD 16 RBD	4 (36%) LBD 10 (62%) RBD **[RBD >LBD]**		Significant correlation CA and performance in perceptual discrimination task in RBD, but not in LBD
Kirk and Kertesz, 1989		28 LBD 41 RBD	LBD performed worse than RBD in the overall accuracy		Significant correlation CA and performance in visuo-peceptual task (Raven Test) in RBD and LBD
Carlesimo, Fadda and Caltagirone, 1993	- graphic copying,	29 LBD 27 RBD 27 control	10 (34%) LBD 8 (30%) RBD **[RBD =LBD]**		Significant correlation CA and performance in visuo-peceptual task and finger tapping in LBD; and between CA and visual tracking

Several major studies found CA at a higher frequency in RBD than LBD patients (Arrigoni and De Renzi, 1964; Griffiths and Cook, 1986; Piercy et al., 1960; Piercy and Smyth, 1962). These assessments were mostly based on the accuracy of the reproduction, evaluated as resemblance between the drawing and the original shape. In some studies, the copy drawings were simply scored as recognizable or not (Piercy et al., 1960; Piercy & Smyth, 1962). In others, the accuracy was assessed using a 0 (unrecognizable) to 2 (recognizable) point scale, considering scores below the performance of the worst control as pathological performance (Arrigoni & De Renzi, 1964; Arena & Gainotti, 1978).

The hypothesis of different cognitive nature of CA between LBD and RBD patients dates back to Duensing (1953), who observed that drawings of LBD patients were characterized mostly by simplifications and omissions. In contrast, RBD patients showed major errors in orientation and reproduction of the spatial relationships between the different elements of the drawing. Therefore, the author posited a different nature of CA depending on the hemispheric locus of the lesion: executive deficits would be responsible for CA in LBD, while visuospatial or perceptual alterations would cause CA in RBD patients (Duensing, 1953). As shown in Table 1.2, several studies assessing the typologies of CA in the two groups of patients found similar evidence, supporting the existence of an executive form of CA in LBD (Piercy, 1960; Warrington et al., 1966) and a visuospatial form of CA in RBD (Gainotti & Tiacci, 1970).

Further studies aimed to test the hypothesis of the executive nature of CA in LBD patients, employing graphic copying tasks with landmarks previously marked on the paper (Gainotti, Miceli & Caltagirone, 1977; Hécaen & Assal 1970; Pillon, 1981). These tasks are designed to reduce the planning aspect of the original graphic copying task. The hypothesis of an executive nature in LBD patients predicts an improvement in performance with landmarks (Gainotti, Miceli & Caltagirone, 1977; Hécaen & Assal 1970; Pillon, 1981). This hypothesis was supported by Hécaen and Assal (1970), who showed improvement in performance of LBD patients, while no benefit from landmarks appeared for the RBD patients. Moreover, correlational studies showed a significant relationship between drawing performance and visuoperceptual tasks in RBD but not in LBD patients (Costa & Vaughan, 1962; Griffiths & Cook, 1986; Kirk & Kertesz, 1989; Piercy & Smyth, 1962).

The dominance of the right hemisphere in CA and the different nature of CA depending on the hemisphere of the brain lesion are not unanimous findings. As shown in Table 1.2, several studies found no significant difference in the frequency of CA between right and left brain-damaged patients (Arena & Gainotti, 1978; Carlesimo Fadda & Caltagirone 1993; Kirk & Kertesz, 1989). Moreover, the evidence of a different CA nature in right and left brain-damaged patients has not been replicated in other studies. Gainotti, D'Erme and Diodato (1985) found similar patterns of drawing errors in patients with right and left hemisphere damage. Similarly, the specific executive nature of CA in patients with LBD has not been confirmed by further studies, which found no specific improvement in patients with LBD in a landmark guided drawing task (Gainotti, Miceli & Caltagirone, 1977; Pillon 1981). Moreover, Arena & Gainotti (1978) found a significant correlation between CA and visuo-perceptual task performance in both right and left brain-damaged patients. Similarly, Trojano et al. (2004) found a similar performance between right and left brain-damaged patients in both constructional and visuo-spatial tasks.

A better agreement among the different studies concerns the preferential involvement of the parietal lobe in CA. Since Kleist's initial observation (1934) this syndrome has been considered to be related to lesions in the occipital-parietal area, which might cause a disconnection of perceptual and motor process (Benson & Barton; 1970; Critchley, 1953). Moreover, recent research (Makuuchia, Kaminagab, & Sugishita, 2003) investigated the neural correlates of drawing using functional magnetic resonance imaging (fMRI). Seventeen young participants were presented with pictures of familiar objects and were asked in one condition to silently name the pictures and in another condition to silently name the pictures and to copy the image in the air using the index finger. The results showed a greater activation of both left and right parietal lobes in the copy drawing condition compared to the naming condition, supporting the hypothesis of the primary involvement of the parietal lobes in the drawing process.

Despite its preferential association with parieto-occipital lesions, CA can also appear as a consequence of focal damage to a range of brain areas, including frontal and subcortical regions (Benson & Barton, 1970). However, the impairment of constructional skills as a result of a posterior lesion appears to be more severe than CA subsequent to anterior lesions (Arena & Gainotti, 1978; Black & Scrub, 1976; De Renzi & Faglioni, 1967; Villa et al., 1986).

To summarize, damage in the right and/or left hemisphere (Gainotti et al., 1985; Rogers, 1996) and in several areas of the brain can cause CA. Considering this wide diversity of responsible lesions, it is perhaps not surprising that CA is one of the common symptoms of dementia.

CONSTRUCTIONAL APRAXIA: A SYMPTOM OF DEMENTIA

CA can appear not only as a consequence of a focal brain damage, but also as an expression of a more general cognitive impairment (Carlesimo, Fadda, & Caltagirone, 1993). Therefore, CA is one of the symptoms commonly observed in dementia (Gainotti, 1985), though it is usually examined less thoroughly than memory, linguistic, or executive functions. CA is a feature of different forms of dementia, such as Alzheimer's disease (AD), Frontotemporal dementia (FTD), dementia of vascular origins and Lewy body dementia.

Among the different forms of dementia, CA is a common feature of AD (Farah, 2003). In some patients, CA does not appear until the terminal stages; in others, it is an early feature (Della Sala & Spinnler, 1999). CA can even be a major presenting symptom in the absence of memory complaints, a pattern arising in posterior cortical atrophy, which is often considered a variant of AD (Della Sala, Spinnler & Trivelli, 1996). In patients with AD, CA is relatively independent from language or memory impairments (Kirk & Kertesz, 1991) and from a specific visuospatial impairment (Ueda et al., 2002), but appears to be highly correlated with global cognitive decline (Cormack, Aarsland, Ballard, & Tovée, 2004; Guérin, Ska, & Belleville, 2002). Performances of patients with AD in constructional tasks progressively decrease with the severity of dementia (Lee, Swanwick, Coen, & Lawlor, 1996). Spontaneous drawings of AD patients often contain simplifications, the reduction of angles compared to the original model-shape (e.g., triangle vs. square), alteration of the spatial disposition of the different elements composing the drawing, rotations, and a lack of perspective (Kirk & Kertesz, 1991). This pattern of errors does not correspond to any particular focal lesion profile, but may reflect more widespread neuropathology, and a range of cognitive deficits. Some patients with AD might also show specific constructional disability. Grossi, Fragassi, Giani and Trojano (1998) described the case of a patient with AD, who showed severe CA and specific difficulties in reproducing horizontal lines in all the constructional tasks tested (copying, drawing on command) and in no-graphic executive tasks, despite preserved abilities to draw oblique or vertical lines. From a more general point of view, as expected from primary memory deficits, patients with AD often show a marked impairment in drawing from memory (Perry & Hodges, 2000).

As a clinical observation, patients with FTD often show preserved graphic copying skills (Edwards-Lee et al., 1997). However, the emergence of a peculiar artistic talent has also been observed as a consequence of this form of dementia (Miller et al., 1998). It has been proposed that decreased inhibition of the more posterior visual system, as a consequence of degeneration of the fronto-temporal area, might promote the development of artistic abilities in patients with FTD (Miller et al., 1998). From a more general point of view, patients with FTD show more accurate performances than AD patients in graphic copying (Mendez et al., 1996; Miller et al., 1997; Razani, Boone, Miller, Lee, & Sherman, 2001). However, this evidence is not unequivocal. Several studies found a similar graphic copying performance in patients with FTD and with AD (Grossi et al., 2002; Hodge et al., 1999; Pachana, Boone, Miller, Cummings, & Berman, 1996; Perry & Hodge, 2000). Moreover, a similar pattern of errors has been observed in both groups, suggesting that constructional deficits might not distinguish between the two forms of dementia (Grossi et al., 2002).

CA is also a characteristic of dementia of vascular aetiology and Lewy body dementia. Patients with vascular forms of dementia show a performance similar to AD patients in drawing from memory, but they appear more impaired in graphic copying than patients with AD (Libon et al., 1993). As with FTD, several studies showed different results in relation to the appearance of CA in Lewy body dementia compared to AD. Ala, Hughes, Kyrouac, Ghobrial, and Elble (2001) found that patients with Lewy body dementia were more impaired than patients with AD in graphic copying tasks. On the contrary, Connor et al. (1998) found no significant difference in constructional abilities between patients with Lewy body dementia and AD. However, while in patients with AD, CA has been found to be strongly linked with the severity of dementia, in patients with Lewy body dementia the nature of CA appears to be dissociated from the overall cognitive deterioration of dementia (Cormack et al., 2004). Therefore, it has been proposed that in this last group of patients, CA might be related to impairment in the early stages of the drawing process, specifically in the perceptual analysis of the model (Cormack et al., 2004).

Finally, it is worth mentioning that constructional alterations are not confined to pathologies but they can appear in normal aging (Bennett et al., 2003). Although copying abilities have been demonstrated to be sensitive to the aging process (Ericsson, Forssell, Holmén, Viitanen, & Winblad., 1996), non-demented elderly subjects have more difficulties in spontaneous drawing than graphic copying (Gaestel, Amieva, Letenneur, Dartigues, & Fabrigoule, 2006). These difficulties in spontaneous drawing have been hypothesized to be related to both executive problems (De Jager, Hogervorst, Combrinck, & Budge, 2003; Royall, Espino, Polk, Palmer, & Markides, 2004) and mental imagery problems (Gaestel et al., 2006; Guérin et al., 1999). Moreover, depression (Lamberty & Bieliauskas, 1993), gender (men better than women) (Gaestel et al., 2006) and level of education (Ardila, Ostrosky-Solis, Rosselli, & Gómez, 2000; Gaestel et al., 2006) have been reported to be additional factors which influence the performance of normal elderly subjects in constructional tasks.

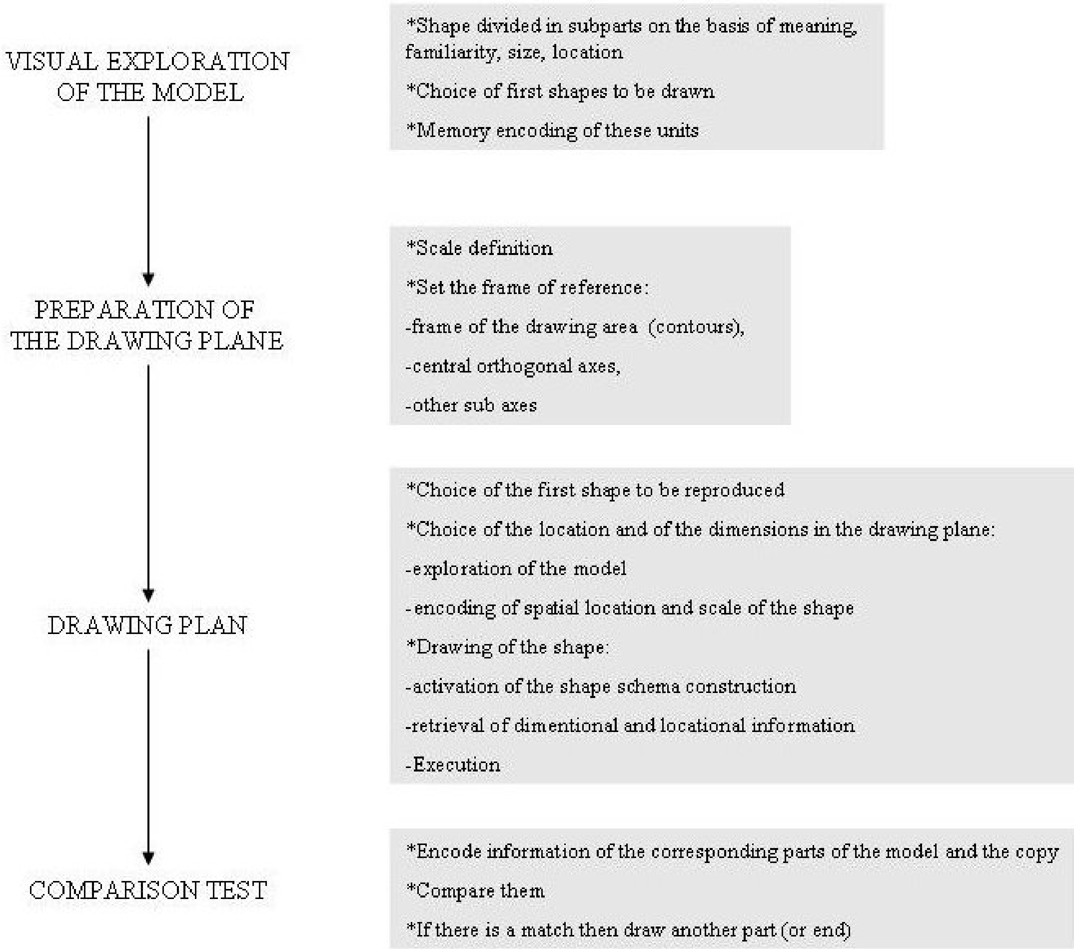
In summary, this brief overview of the studies of CA aimed to give a broad picture of the variety of neuropathologies and cognitive deficits, which might cause the appearance of this syndrome. The variety of outcomes obtained by different studies is evidence of the complexity of this syndrome. For a better understanding of this syndrome, a recent trend in CA studies has been to focus on a specific constructional task, in order to identify the specific cognitive abilities involved (Grossi & Trojano, 1999). The task that will be spotlighted here is graphic copying, and three cognitive models of copying performance will be sketched.

COGNITIVE MODELS OF GRAPHIC COPYING

In this section, three cognitive models developed to describe the different stages of the graphic copying process will be described: Roncato Sartori, Masterson, and Rumiati's, (1987), Van Sommers' (1989), and Grossi and Angelini's (Grossi, 1991; Grossi et al., 1993; Grossi & Trojano, 1999) models. The main purpose is not to give an exhaustive description, but to discuss the key aspects of each model in order to point out the difficulty in formalising the complex process of graphic copying.

The first model was introduced by Roncato et al., (1987) (see also Guerin et al., 1999). The authors postulated four main hierarchical stages of graphic copying (Figure 1.2). In the two first preliminary stages, the subject explores the model to be copied, encodes in memory the elements of the model, and develops a drawing plan, taking decisions about the characteristics of the graphic copy. Then, the copy is executed and compared with the original model in order to monitor the performance. In the execution of the graphic copying, two different strategies can be adopted to perform the graphic copying task: a line by line or a top down copying strategy. The first strategy consists of the independent reproduction of each line or unit of the model and it is based on a system of co-ordinates, which identify the locations of each unit. Therefore, this strategy can be applied without comprehension of the meaning of the entire picture and is used in copying meaningless shapes. Instead, the top-down strategy is based on the recognition of the picture as a whole, followed by the identification of the individual subparts of the model and their spatial relationships.

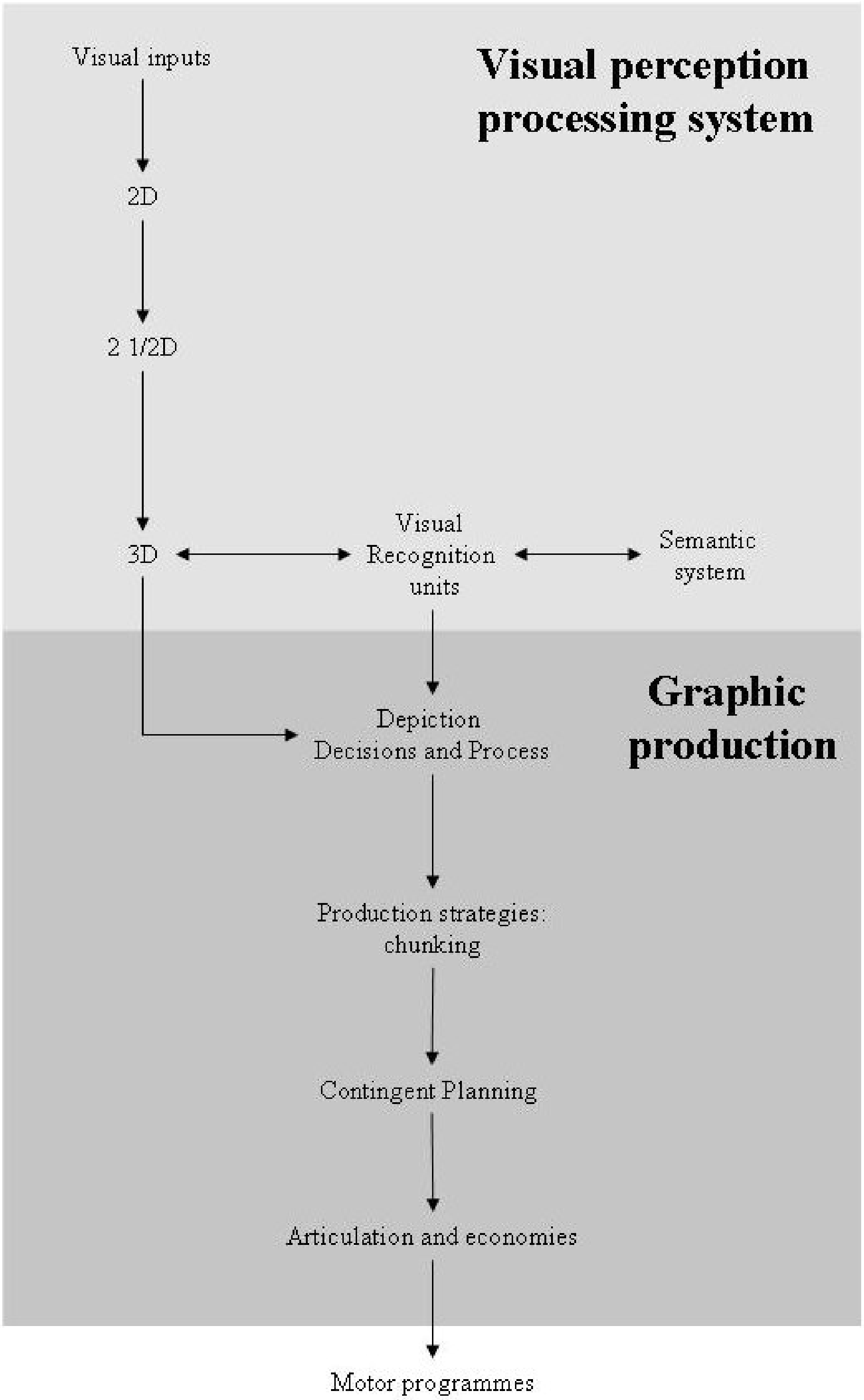
Figure 1.2. Roncato et al.'s (1987) model of copying and description of the graphic copying stages.



The second model was developed by Van Sommers (1989) (see also Guérin et al., 1999) to explain the overall system of drawing (drawing from memory and graphic copy). The present review will focus on the specific aspect of the model concerning graphic copy. As shown in Figure 1.3**,** two main hierarchical processes were proposed to describe the graphic copying process: the visual perception and the graphic production processing. The visual perception process of this model was derived from Marr's (1982) model of the visual system, which proposed different stages of transformations of an image from visual input into a mental representation. The graphic process starts once the internal representation of the visual input is created. Then, the subject decides how to depict the original model (type of object, orientation, viewpoint, dimension, level of details, etc.). The following stage is the *production strategy*, which consists of a segmentation process in which the drawing is chunked into different units. This segmentation can respect the hierarchy of the picture (as in Rey's figure copying task, in executing the copy the big rectangle first) or emerge in a line by line strategy of copying. Once the picture is chunked the *contingent plan* is activated. This stage consists of a problem solving task in which the segmented units are reproduced in a certain sequence**.** This contingent plan is activated in unconventional drawing copying tasks, while in copying conventional drawings a *routine plan* is initiated. The final stage concerns the motor *articulatory and economic* constraints imposed by the use of the drawing tools (pen-pencils). This last stage takes into account the drawing abilities of the graphic motor system (Grossi & Trojano, 1999)

The third model was designed by Grossi and Angelini (Grossi, 1991; Grossi et al., 1993; Grossi & Trojano, 1999). The authors pointed out the importance of top down processing in the execution of the copy and considered constructional tasks as problem solving tasks. Therefore, the graphic copying performance is postulated to be related to the cognitive strategy and the constructional intelligence of the subject. In this cognitive model, three main stages of the copy process were proposed: a preparatory stage, a central processing stage, and the execution stage. The preparatory stage is characterized by a search in the *constructional lexicon,* which constitutes the "long term store for familiar constructional schema" (Grossi & Trojano, 1999, p. 449) of similar pictures drawn in the past (see Figure 1.4). This search is accompanied by the analysis of the spatial relationships between the different elements of the model, and by the assessment of the spatial relationship between the elements of the model and the copy working space. The information derived from the constructional lexicon and from the visuospatial analysis of the model is then integrated to develop a *drawing plan.* This stage implies the definition of different graphic parameters, such as the first shape to draw, the starting point, the scale, the orientation, and position of the copy, etc. The representation of the drawing plan is maintained in short-term memory for the time necessary to perform the copy.

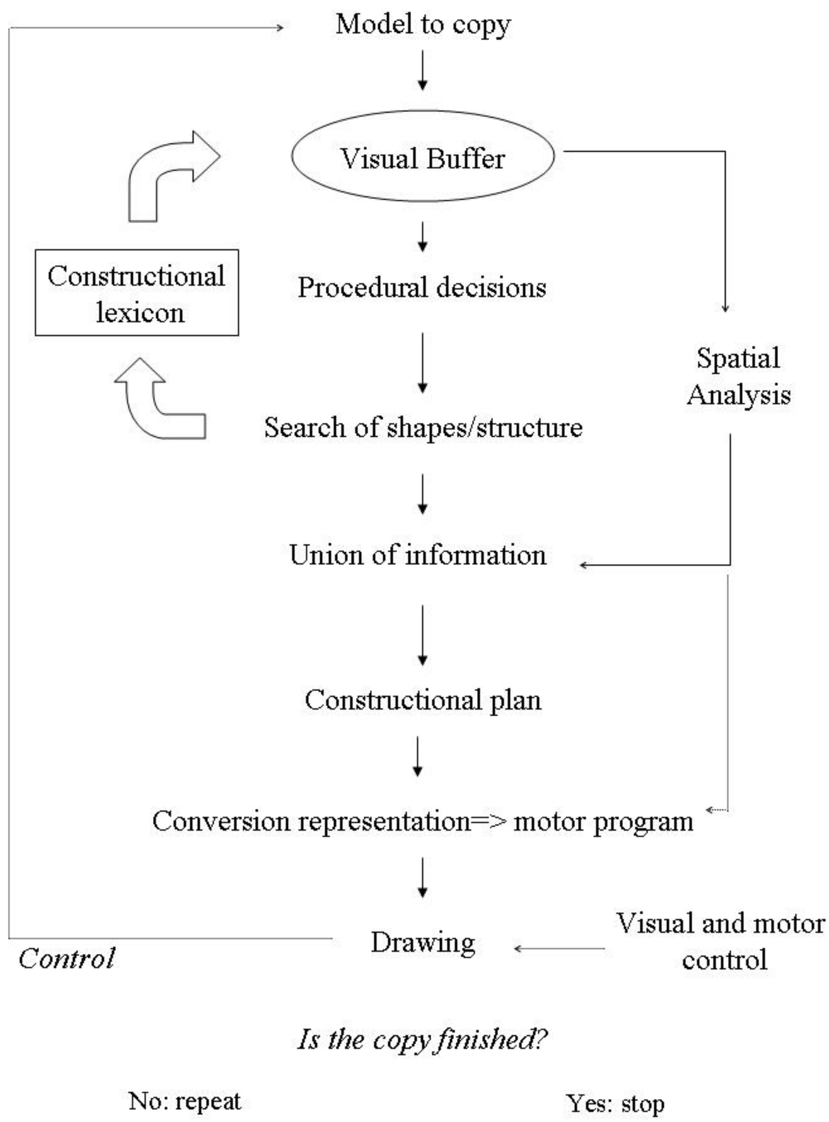
Figure 1.3. Van Sommers' Model (1989)



The constructional scheme developed during this process is then converted into a motor program and the drawing is executed. Two different copying strategies can be applied to execute the copy: a lexical route and a line-by-line procedure. The characteristics of the shapes to be copied and the personal strategy of the subject influence the choice of one of these two copying strategies. While the lexical route uses the constructional schema stored in long term memory, the line-by-line strategy is based on the visuospatial analysis of the model. Both strategies can be applied in copying complex models and they can be selectively impaired in patients. In support of this view, the authors referred to two single case studies in which a double dissociation between the two copying strategies was observed. The first case is a visual agnosic patient described by Wapner, Judd and Gardner (1978), who was unable to recognize visually presented objects and drawings, but was able to accurately reproduce graphic copies using a line by line strategy. Nearly the opposite pattern was observed in another patient with a subcortical lesion of the right hemisphere (Grossi et al., 1996), in whom the lexical route appeared preserved. This patient was able to draw simple shapes, such as circles and squares, but he showed difficulties copying more complex models. Therefore, he was able to reproduce shapes, which can be considered a familiar constructional schema, but he showed impairment using a line-by-line strategy under the guidance of the visuospatial analysis of the model.

Although, the three models have different characteristics, the core stages and procedures of the copying drawing process presents a common substrate (Grossi & Trojano, 1999). Therefore, they involve three main stages of graphic copying (visuospatial analysis, creation of a drawing plan, and execution) and two main copying strategies based either on the reproduction of each element separately or of the shape as whole. While the first strategy is based upon the continuous visuospatial reference to the model, the second is based on the retrieval of the shape from memory. Moreover, with different levels of emphasis, all these models consider the graphic copying task as a problem solving task, in which the personal cognition, strategy, and intelligence of the subject play an important role.

Figure 1.4. Grossi and Angelini's (Grossi, 1991; Grossi et al., 1993; Grossi & Trojano, 1999) model of copying



Although noteworthy, none of these models have received a general acceptance, because they have not been clinically or experimentally tested (Grossi & Trojano, 1999). This lack of empirical evidence mirrors the difficulty of a cognitive model of graphic copying to incorporate all the different cognitive abilities involved in copying drawing tasks and to predict and explain all the specific constructional errors (Grossi & Trojano, 1999). Nonetheless, these models represent a first step toward a different approach in the study of CA, which aims to reduce the complexity of CA by focusing on a specific constructional task.

CONCLUSIONS

The present chapter has reviewed a number of different studies of CA, and highlighted factors which might contribute to the heterogeneity of results among researches. This literature might have inspired confusion in the reader. This confusion directly mirrors the ambiguity in CA literature, characterized by a constant tension between qualitative and quantitative assessment of CA; between the consideration of CA as unique syndrome or a broad label that incorporates a variety of disorders.

First, this review aimed to show that a variety of errors can arise in constructional tasks and the broad label of CA cannot be taken to imply any specific cognitive impairment (Farah, 2003). Constructional tasks may be sensitive to different disorders, but they lack specificity in differentiating between them. As mentioned before, impairment in the performance of these tasks can be due to a variety of neurological disorders and cognitive deficits (Grossi & Trojano, 1999). Furthermore, the different constructional tasks (drawing from memory and graphic copying) appear to measure different cognitive abilities, which can be affected at different levels in single patients. Even by focusing attention on a single constructional task, such as graphic copying, differences between single tests (copy of cube vs. copy of a house) can still be observed (see Constructional Tasks and Scoring Procedures)

Moreover, this review discussed the methodological issues regarding CA assessment, pointing at the difficult evaluation of the drawing production and the difficult dissociation between the accuracy of the copy as a whole and the presence of specific constructional errors. Therefore, if the presence of a specific constructional problem reduces the accuracy of the copy, it may also reflect a combination of cognitive impairments (Guérin et al., 1999). Moreover, where constructional errors are recognised as characteristic of specific cognitive impairments, they tend to attract specific labels (e.g. perseveration, neglect), rather than being classified as CA.

The current trend in the study of CA, which proposes to focus on the study of a specific constructional process, such as graphic copying, has been examined. The cognitive models of graphic copying have been described, as well as their difficulty to predict the different graphic behaviours and cover all constructional error manifestations. Therefore, this cognitive neuropsychological approach, which aims to identify the series of cognitive components and their association in graphic copying processes, might not be entirely suitable in the comprehension of CA. Since it has been argued that CA operates, clinically, as an umbrella term for heterogeneous drawing or building errors of unknown cognitive origins, a possible alternative approach to reduce the multicomponential nature of CA would be to investigate the cognitive nature of a specific manifestation of the syndrome (Smith & Gilchrist, 2005).

In line with this approach, the present thesis proposes the study of a specific constructional manifestation, Closing-in Behaviour, which appears in graphic copying tasks. The next Chapter will review the prior literature on CIB, and define a general methodological framework for the empirical portion of this thesis.

CHAPTER 2
Closing-In Behaviour

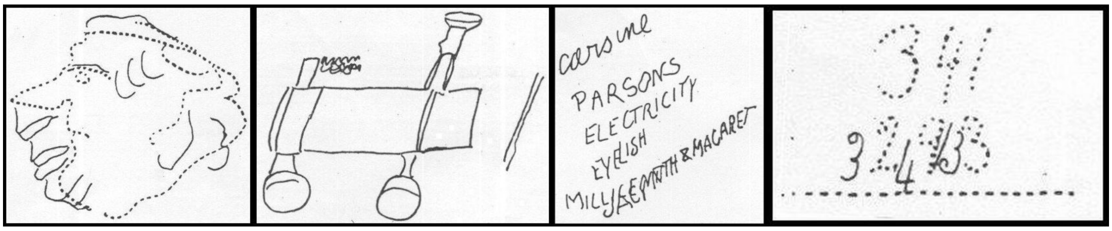
EARLY REPORTS

One idiosyncratic manifestation of CA that has received relatively little attention in the neuropsychological literature, was first described by Mayer Gross (1935) in a patient with carbon monoxide poisoning and in five patients with probable dementia. These patients were able to copy simple geometric figures, whether by drawing or arranging mosaic tiles or blocks, but when the complexity of the model increased they would attempt to copy directly next to, or even on top of the model. This tendency was previously noted (in passing) by different authors (Goldenstein, 1928; Lhermitte, de Massary & Kyriaco, 1928), but Mayer Gross (1935) was the first to recognize it as a specific phenomenon and to describe it in detail. In copying mosaics for instance, his patients were able to understand the task and recognize the different colours. They were able to name the colours composing the mosaic in the correct order, but once they were asked to perform a copy, they placed the elements very close or on the top of the original. The patients were also able to recognize that their performance was incorrect. A similar tendency emerged in the imitation of hand postures, during which the patients' hand would sometimes overlap that of the examiner.

The case described most extensively by Mayer Gross (1935) was a patient with dementia who was an artist before the onset of his dementia. This patient showed CIB in conjunction with CA. His drawing abilities were comparable to those of healthy elderly, but simplistic compared to his own previous artistic accomplishments. His reproductions from memory were recognizable but unadorned and characterized by spatial misplacement of elements (see examples in Figure 2.1). In graphic copying of partially structured models made up of dots, the patient showed a strong tendency to perform the copy on the top of the model (Figure 2.1). When the examiner repeatedly asked him to perform the copy alongside the model, the patient could detach from the model and draw in the correct space, but for a very short time. Then, he quickly turned back to the original model. In writing, he superimposed his writing upon previously written letters, and in arithmetic calculations, he superimposed the resultant numbers onto the digits to be summed (see Figure 2.1). Mayer Gross interpreted these behaviours within a broader theory of CA, as manifestations of a “primary biological protection mechanism” related to the “fear of empty space” (p.71). His theoretical account, however, has had a less enduring influence than his coinage of the term Closing-in behaviour (CIB) to describe the peculiar attraction to the model.

Figure 2.1. Performance of the artist with dementia described by Mayer Gross (1935).

From the left panel: CIB in graphic copying (the dotted lines represent the original model, while the unbroken line is the patients’ graphic copying); drawing from memory of a train (the train is accurately reproduced but the tracks are misplaced); CIB in writing (the letters are superimposed) and arithmetic calculations (the dotted number represent the arithmetic sum the patient was presented with, while the unbroken numbers is the sum that the patient computed).



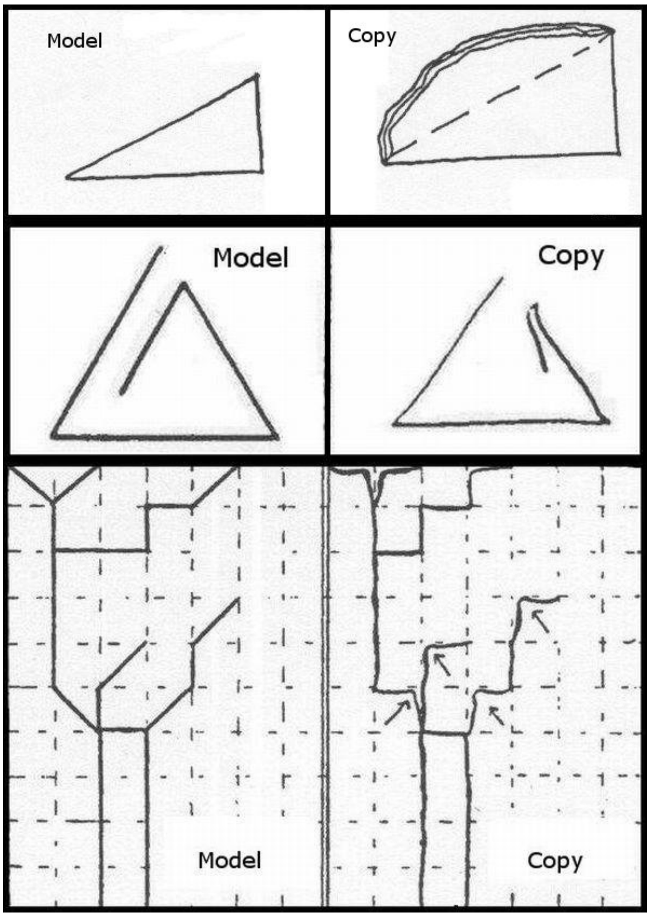
Mayer Gross’s (1935) definition of this phenomenon gave rise to some initial confusion regarding the appearance of CIB. Most broadly, CIB was considered as any kind of tendency to act toward a model, either concrete or abstract. For instance, Muncie (1938) described three cases: a patient with arteriosclerosis, a pre-school girl, and a young schizophrenic sailor. In a patient with arteriosclerosis, he interpreted as a form of CIB, not only the tendency to perform the copy on the top of the model in a constructional task, but also to produce repetitive speech, echolalia, and echopraxia. The three-year-old girl needed a constant reference to a concrete object in order to further develop an abstract representation of it. Therefore, when the author showed her a picture of an object, she picked up the concrete object and placed it next to the picture. The schizophrenic sailor was unable to understand the abstract meaning of a metaphor and he put in action its literal meaning. In a difficult emotional state, the sailor read in a newspaper the metaphor “Never let us cast a shadow by turning our back on the Sun" (p. 8). He put this metaphor into action, facing the sun, climbing and pretending to swim into the bay.

In a similar vein, Vereecken (1958) reported CIB in two cases: a thirteen-year-old girl with visuo-spatial disturbances and a twenty-year-old woman with encephalitis. Both patients showed a specific difficulty in drawing oblique lines in graphic copying as well as in drawing from memory. The author interpreted as CIB the compensatory behaviour the patients used to overcome their difficulties in the reproduction of oblique lines. Therefore, CIB was defined as the tendency to connect two extremities of the model with a curved line, as well as the inappropriate use of the graphic paper to support the copy, and the tendency to close open spaces when copying open shapes (Figure 2.2). Although the possible dissociation between a spared ability to draw vertical lines, with a specific impairment in drawing and mentally representing horizontal and oblique lines has been supported by a subsequent study (Grossi et al, 1998), the compensatory strategy to overcome these deficits described by Vereecken (1958) would not be classed as CIB according to most authors.

To reduce the general confusion on what it would count as CIB, Critchley (1953) proposed circumscribing the phenomenon to constructional tasks and excluding the appearance of the phenomenon in gesture imitation. The author maintained that CIB should be conceived as a symptom of CA, indicative of parietal lobe dysfunction, and that this label should be restricted to the domain of graphic copying and constructional copying using three-dimensional structures (sticks or blocks). Moreover, Critchley distinguished two types of CIB: the tendency to superimpose the copy with the model and the tendency to perform the copy close to, or touching the model. Case reports featuring similar phenomena have appeared in the literature subsequently (see next section), confirming that an attraction toward a model can arise across a wide range of copying tasks (e.g., graphic, 3D construction, gesture, and writing).

Figure 2.2. Examples of geometrical model used to assess CIB (left panels) and graphic copying performances described as CIB by Vereecken (1958) (right panels).

In copying the triangle (upper row) the patient was unable to copy the oblique line (the dashed line was traced by the author) and connected the two extremities of the shape with curved lines. In copying the triangular geometrical shape (middle row), the patient drew the last line close to the previous one. In following a pattern on a graphic paper (lower row), the patient was unable to draw the oblique lines and therefore followed the pattern of the graphic paper.



CLOSING-IN BEHAVIOUR IN CONSTRUCTIONAL TASKS AND IMITATION

Despite the initial broad interpretation regarding the specific manifestation of CIB, the single case studies presented in the literature (see Table 2.1) described the appearance of the phenomenon in mainly three different domains: constructional tasks, imitation of gestures, and writing.

Table 2.1. Observations of CIB in different domains and in association with CA

	CIB				CA errors drawing from memory
	Graphic copying	3D construction	Gesture	Writing	
Mayer Gross, 1935	√	√	√	√	Spatial distortions
Muncie, 1938	√	√	x	x	Spatial distortions
Lhermitte and Mouzon, 1941	√	√	x	x	Unable to draw from memory
Stengel and Vienna, 1944	x	x	x	√	
De Ajuriaguerra, Zazzo, and Granjon, 1949	√	√	√	√	Spatial distortions, simplifications, perseverations
De Renzi, 1959	√	√	x	x	Spatial distortions
Pavan, 1966	√	√	x	x	
Kuroiwa et al., 1967	√	x	-	x	Omission and simplifications
Cipollotti and Denes, 1989	√	-	x	x	Spatil distortions, omissions scrawl
Grossi et al, 1996	√	-	-	-	Spatial distortions
Kwon et al., 2002	x	-	√	x	Severe CA
Suzuki et al., 2003	√	√	-	√	Drawing on command is simplified but mild CA
Conson, Salsano, Manzo, Grossi, and Trojano., 2009	√	-	x	-	Drawing on command better than copy drawing CIB

√ symptom present; x symptom absent; - symptom not tested

Another aspect of the appearance of CIB in constructional tasks is the association between this behaviour and CA. As shown in Table 2.1, most of the patients with CIB performed poorly, not only in graphic copying, but also in drawing from memory. The drawings of patients with CIB are often characterized by spatial distortions, omissions, and simplifications, and are occasionally nothing more than a scrawl. This association engenders the idea that CIB is a specific sub-symptom of CA (Critchley, 1953), likely to appear with severe CA (Conson et al., 2009). This idea found further support in studies on patients with dementia, which showed a parallel increase of both CIB and CA frequency with the dementia severity (De Ajuriaguerra, Muller, & Tissot, 1960; Gainotti, 1972). However, two recent single case studies (Conson et al., 2009; Suzuki et al., 2003) reported CIB in graphic copying in conjunction with mild difficulties in drawing on command.

Although the phenomenon has been most commonly observed in graphic copying, CIB has been reported across a wide range of tasks, including imitation of gestures and writing (see Table 2.1). For instance, Kwon et al. (2002) reported the case of a patient with corticobasal degeneration, who performed poorly in constructional tasks, without however showing CIB. The phenomenon appeared when the patient was asked to imitate nonsense gestures. In conjunction with severe ideomotor apraxia, the patient showed the tendency to approach, to touch, to overlap, and sometimes even to grasp the examiner's hand. Stengel and Vienna (1944) reported the case of a patient with severe CA without CIB, who superimposed his writing upon previously written letters. Although the interpretation of this behaviour in spontaneous writing as CIB, rather than a form of agraphia, can be questionable, Mayer Gross (1935) had already mentioned the appearance of CIB in spontaneous writing as the tendency to anchor the writing to visible marks on the paper. The assessment of CIB in copying letters or words is more easily inferred, and has been reported in two studies. The first study (De Ajuriaguerra et al., 1949) described the behaviour of a patient, who in copying letters of the alphabet, first traced the original model and then started to write next to the model but overlapping single letters. Several years later, Suzuki et al. (2003) reported two patients who showed CIB in constructional tasks and in copying kanji characters. A broad definition of CA is that it incorporates any impairment in arranging the different elements composing a shape in the correct spatial relationships (Kleist, 1934). Following this definition, writing might also been considered as a constructional task and the appearance of CIB in copying letters, words or ideograms may be comparable to CIB in graphic copying.

A relatively common observation about CIB is that the phenomenon in both constructional tasks and gesture imitation appears to be influenced by the complexity of the copying task. The operationalisation of complexity in graphic copying tasks is challenging, since complexity can be defined in relation to many different factors, including the dimensionality of the picture (2D vs. 3D), the number of sub-shapes, the number of colours composing the model, and the degree of organization of the shape. These examples highlight the consequent difficulty of systematically controlling this variable. In the different studies of CIB, this ambiguity in the definition of the task complexity becomes specifically evident.

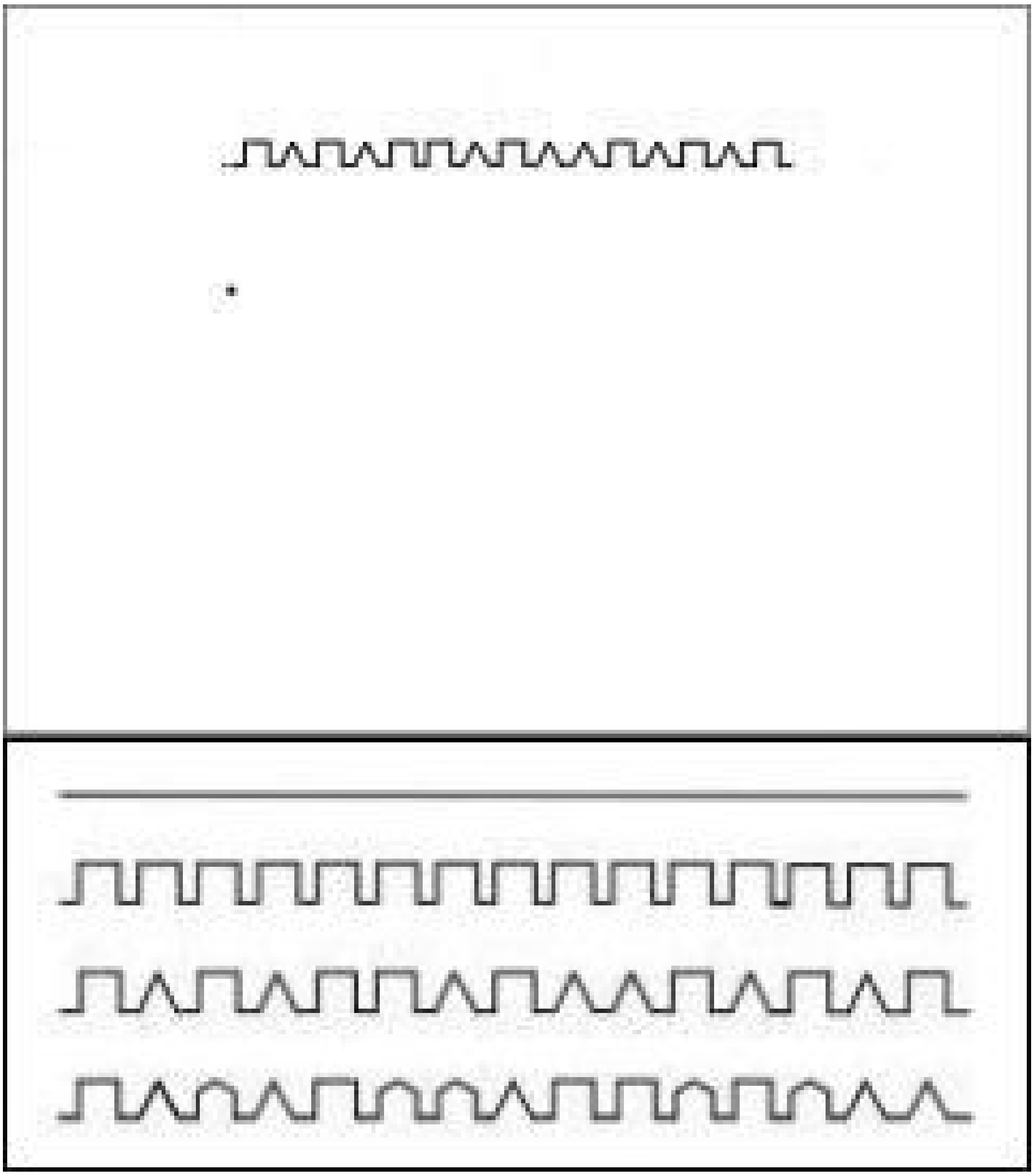
The literature of CIB is characterized by common but not unanimous results regarding the complexity effect on CIB, which can be perhaps explained with relation to different parameters used to define this variable. Mayer Gross (1935) was the first to mention that the tendency to perform the copy on the top of the model emerged with more complex tasks. A few years later, Muncie (1938) found similar evidence: his patient was able to copy simple geometrical shapes, but showed CIB in copying shapes made up of two colours and performed the drawing on the top of one colour. However, Muncie's patient showed a specific difficulty in colour naming tasks, and a tendency to close toward the model in colour matching tasks. This specific deficit might have caused the major difficulty of copying two coloured shapes in this patient with the consequent increase of CIB, which has never been confirmed in other studies. De Renzi (1959) found the tendency to close toward the model to be more common in copying open and less structured shapes (e.g., simple lines or a cross) than in copying closed shapes (e.g., a triangle). Similarly, the patient described by Pavan (1966) was able to draw simple geometrical shapes but overlapped the copy with the model when asked to copy more complex drawings, such as a house. These patterns have been generally replicated in a larger samples of patients with AD (Grossi, Orsini, & De Michele, 1978; Lee et al., 2004). Grossi et al. (1978) showed that CIB was more likely to appear in 3D or multipart shapes copying tasks, rather than simpler 2D geometrical shapes. However, this effect of complexity of the graphic copying task on CIB has not been observed in all studies. For instance, Conson et al. (2009) found no significant difference in the frequency of CIB in copying simple 2D or complex 3D shapes in a patient with corticobasal degeneration. Parallel results were obtained by Kwon et al. (2002) in gesture imitation. Their patient showed comparable CIB in both simple and complex gesture imitation tasks.

A novel and more systematic approach to the manipulation of the complexity of the copy was introduced recently by Lee et al. (2004). The investigators did not use the common geometrical shapes copying tasks to assess CIB, but different variations of the Luria's figure (Luria, 1966) (see Figure 2.3). This shape was initially used by Luria to explore graphic abilities and motor control in brain damaged patients, with damage involving in particular fronto-temporal areas. The original shapes consisted of square units or square and triangular units. Patients were asked to use one continuous movement to either to draw from memory or copy this shape as quickly as they could. One advantage of this type of shape in the assessment of CIB consisted in the laterally extensive structure of the picture, which allows the assessment of the development of CIB in the course of the graphic copying from the left to the right edge of the sheet of paper. This procedure also offered a more controlled assessment of the effect of complexity, as the number of different geometrical elements varied between none (straight line), one (square), two (square and triangle) or three (square, triangle and pentagons) (see Figure 3). Moreover, the degree of predictability of the shapes was also manipulated. Using this more controlled methodology, Lee at al. (2004) found that the tendency to perform graphic copying toward the model in patients with AD significantly increased with the complexity of the copying tasks.

A possible, very tentative, interpretation of the conflicting results in the literature of CIB is that the phenomenon might be sensitive to the effect of the complexity of the task only when it is associated with functional alterations, likely related to some specific neuropathologies. Therefore, the aforementioned studies above, reporting CIB with more complex shapes, refer to single cases or patient group suffering from dementia and of a possible Alzheimer's type (Grossi et al., 1978; Lee et al., 2004; Mayer Gross, 1935). On the contrary, lack of effect of complexity has been found in patients with corticobasal degeneration or carbon monoxide intoxication (Conson et al., 2009; De Ajuriaguerra et al., 1949; Kwon et al., 2002).

Figure 2.3. Representation of Luria's figure copying task (top panel) and the four level of shape complexity used by Lee et al. (2004).

These levels of shape complexity are the straight line copying task, and the three manipulations of Luria's figure composed of square units (low complexity), squares and triangles units (medium complexity) and squares, triangles and, pentagons units (high complexity). An additional element which increases the complexity of the last two figures is the unpredictability of the sequences of elements composing the shape.



Taken together, these findings show that CIB can appear in a variety of tasks and cognitive domains. In some cases, CIB might equally affect graphic, gesture, and writing task, while in others the phenomenon might be selectively observed in a specific cognitive domain. This evidence may suggest that specific subtypes or forms of CIB exist in relation to each specific cognitive domain. An alternative explanation of the appearance of CIB in a variety of cognitive tasks is that CIB is a general phenomenon, not associated with any narrow range of constructional demands. However, the specific structure of the copying tasks has been often recognized to play an important role in the appearance of the phenomenon. CIB is likely to appear in complex tasks. As previously discussed, the results in the literature are somewhat ambiguous and depend upon the specific definition of the complexity of the task applied. Moreover, it has been speculated that this effect of complexity might concern just specific functional forms. This hypothesis is speculative and further studies need to test this interpretation.

METHODOLOGICAL APPROACHES TO THE STUDY OF CLOSING-IN BEHAVIOUR

Although Critchley (1953) tried to clarify the concept of CIB and its manifestation, the confusion in the studies of CIB persisted and to a certain extent even increased. The close association between CIB and CA stated by Critchley (1953) induced several authors to classify the phenomenon as one of the possible errors in constructional tasks and therefore CIB was often scored on the same scale with other CA errors (Cosentino, Jefferson, Chute, Kaplan, & Libon, 2004; Rouleau, Salmon, & Butters, 1996). A further outcome of the interpretation of CIB as CA manifestation has been the common assessment of CIB in conjunction with the accuracy of the copy. Since the phenomenon has often been considered an intrinsic aspect of CA, the misplacement of the copy automatically corresponded with a low score in constructional skills. As an example, the scoring procedure of one of the most common and recognized neuropsychological subtest for the assessment of constructional ability in the Italian population (Arrigoni & De Renzi, 1964, in Spinler & Tognoni, 1987) is based on 0 (minimum score) - 2 (maximum score) point scale. Graphic copying performances are scored as 0 if the reproduction shows either a poor accuracy (scribble) or if the copy is placed close to or on the top of the model. This classification, used in a study of CIB (Grossi et al., 1978) was based on the theoretical assumption that CIB is not an independent phenomenon but is a symptom of severe constructional alterations. On the contrary, the assessment of CIB independently from the accuracy of the reproduction might avoid the possible underestimation of the accuracy of the copy in the presence of CIB (Conson et al., 2009) and allow the consideration of the two as separate events.

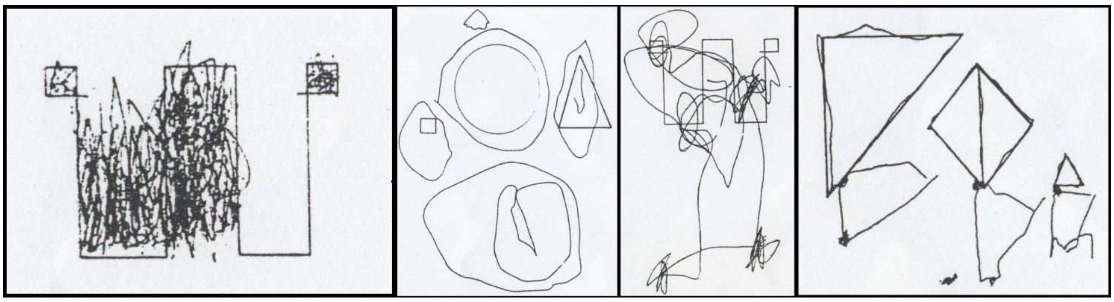
Although several authors applied Critchley's (1953) definition of CIB as a boundary circumscribing the appearance of the phenomenon in constructional tasks (see Table 2.1), others applied a more general framework and explored the phenomenon in gesture imitation (Kwon, 2002; McIntosh et al., 2008) and writing (Suzuki et al., 2003). Moreover, the unsolved ambiguity in the definition of CIB had a direct effect on the methodological procedures applied to assess the phenomenon in different studies. Although a variety of methodological approaches emerged in the CIB literature, three main classes could be distinguished.

The first approach consisted in describing the phenomenon in single case studies (Grossi et al., 1978; Kuroiwa et al., 1967; Muncie, 1938), as well as in larger samples of patients (Gainotti, Marra, Villa, Parlato, & Chiarotti, 1998; Gasparini et al, 2008; Gragnaniello, Kessler, & Bley, 1998; Lorenzo-Otero, 2001), from a qualitative point of view. This approach consisted, in most of the cases, in the evaluation of the presence of the phenomenon, without distinguishing between the different possible manifestations of CIB (Critchley, 1953;De Ajuriaguerra et al., 1949; De Ajuriaguerra et al., 1960; De Renzi, 1959; Grossi et al., 1996; Kuroiwa et al., 1967; Lhermitte and Mouzon, 1941; Mayer Gross, 1935; Muncie, 1938; Pavan, 1966). As an example, Grossi et al. (1996) categorized CIB as the tendency to partially overlap the model with the copy; or to trace some lines from the model toward another part of the paper; or when the graphic copying touched the division line, which separated the model space from the copy.

This approach of grouping together these different behaviours under an unique label indirectly implies that these different forms of CIB lie on a continuum of severity, and therefore they might share common causes. This *continuum* *assumption* became more prominent in methodological approaches that aimed toward a specific description of the different CIB manifestations, although without explicitly grading them for severity. In particular, Gainotti (Gainotti, 1972; Ganotti & Kluzer Usuelli, 1972) singled out four different types of CIB: the scrawl inside the model, the "overlap or bound" CIB, the tendency "to trace lines from the model to the surrounding space" (Gainotti, 1972, p. 431), the near or adherent CIB, and the tendency to "trace unsettled lines on the model" (Gainotti, 1972, p. 431) (see Figure 2.4 for an illustration of the first four CIB types). This listing of CIB types aimed to provide an exhaustive and specific overview of the different possible manifestations of this behaviour in graphic copying task. This categorization just partially achieved this goal since specific scoring procedures were not defined**.** This is particularly crucial for the assessment of the *near-type* of CIB, in order to define the limit between a normal and pathological tendency to perform the graphic copying close to the model. Another aspect, which limits the application of these CIB classes, is the difficulty in scoring a single graphic copying production using a unique CIB category (e.g., Overlap CIB). In his studies, Gainotti (Gainotti, 1972; Ganotti & Kluzer Usuelli, 1972) scored a single graphic copying production using multiples labels (e.g., scrawl and near).

Figure 2.4. Four of the five types of CIB described by Ganotti and Kluzer Usuelli (1972).

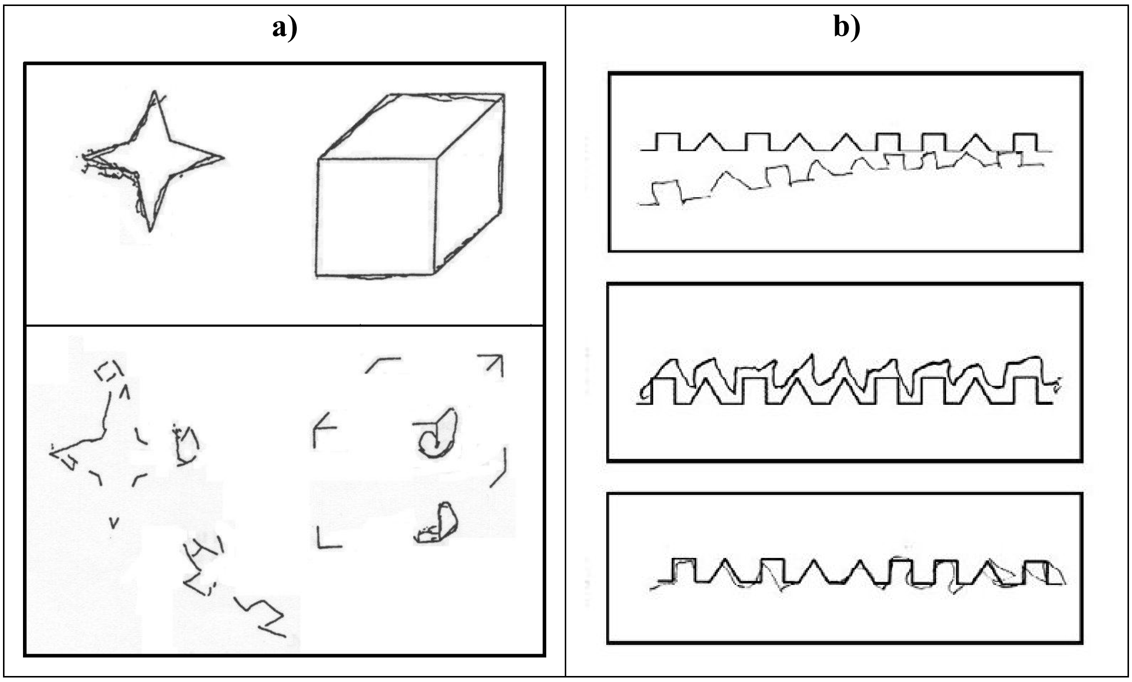
From the left panel: scrawl on the top of the model, overlap or bound CIB, transport, and adherent CIB.



The second approach in the assessment of CIB tries to incorporate the qualitative aspects of the phenomenon with a certain degree of quantification, explicitly grading the different manifestations of CIB on a continuum of severity. As an example, Ober, Jagust, Koss, Delis, and Friedland (1991) graded CIB using a scale from 5 (no CIB) to 1 (copy performed on the top of the model) without explicitly defining the specific manifestation of the phenomenon for each level of severity. Similarly in the assessment of CIB in gesture imitation, Kwon et al. (2002) used a 0-3 point scale, which incorporated the qualitative description of CIB with a definition of different degree of severity. Therefore, they considered three levels of CIB severity: 1) tendency to approach but not touch the hand of the examiner; 2) the touch and the overlap of the examiner's hand, 3) the direct grasp of the examiner's hand. Although this scale was designed to assess CIB specifically in gesture imitation, it represents a novel approach in the assessment of CIB, consisting in the evaluation of this behaviour as an independent phenomenon. For instance, as previously mentioned, the position of the copy was classed as one element of the accuracy of the copy in earlier scales, and therefore CIB was never scored as an independent phenomenon.

The final approach is based on the identification of an operational definition of CIB in relation to the specific task used to assess this behaviour, often applying quantitative measures of the phenomenon. Gainotti, Parlato, Monteleone, and Carlomagno (1992) assessed CIB using a square, a cube and a house shapes, in a classical copying tasks condition, as well as in copying with the help of landmarks marked on the paper. In the copy with landmarks condition, a variant form of CIB was defined the tendency to create a series of independent shapes using the landmarks (sees Figure 2.5a). In the same way, other studies (Chin et al., 2005; Kwak, 2004; Kwak, Han, & Kim, 2002; Lee et al., 2004) used different variations of the horizontally extensive Luria's figure (Luria, 1966), presented on the top of the paper. Performance of young adults was used to establish the criteria to classify the pathological range of performances. Kwak (2004) did not instruct young participants about the starting and the end-point of the graphic copy. Therefore, they used the distances between the start and the end points of the graphic copy of young adults in order to operationally define the different typologies of CIB. Three main CIB categories were identified: the overlap CIB (lines of the copy overlap the model); adherent (copy performed close to the model; difference with young adults >3 standard deviations (*SD*)); near CIB (end point of the copy is close to the model: difference with young adults >3 *SD*) (see Figure 2.5b). The use of this graphic copying task and of a similar methodological procedure has also been applied in other studies to score CIB using more quantitative measures (Chin et al., 2005; Lee et al., 2004). In these studies, the regression coefficient or the slope of the graphic copying toward Luria's figure was used as a measure of CIB, given a predefined starting point of the copy. For instance, CIB was scored when the regression coefficient of the graphic copying was higher than the mean ± 2 *SD* performance of young adults.

Figure 2.5. a) classical (top row) and variant (bottom row) CIB, described by Gainotti et al. (1992); b) near (top row), adherent (central row), and overlap (bottom row) CIB, described by Kwak (2004)



To conclude, the review of the classifications of CIB applied in previous studies, underlines the variety of approaches in the assessment of the phenomenon, which directly implies the difficulty in comparing data across different studies. A trade-off similar to the one described in the previous chapter emerged in CIB literature too. The variety of the approaches in the literature of CIB ranges from more qualitative, but often very subjective, scoring procedures, and more quantitative approaches, which aim to establish a formal and replicable assessment of the phenomenon, but are very task specific**.** The heterogeneity in CIB assessments extends beyond the specific scoring procedure to the variety of tasks used. The establishment of an unambiguous and widely recognized definition of the phenomenon is still an ongoing goal, as well as standardised categorisation of sub-types and/or quantification of severity.

From the analysis of this literature the need to establish a new direction in the study of CIB emerges. Future researches should be oriented toward developing a more systematic approach in the assessment of CIB, providing more detailed operational definitions, as well as scoring procedures**.** In order to explore if the different CIB types lie on a continuum of severity and have similar cognitive origins, future studies should also investigate the different manifestations of this phenomenon, independently, from one another. Finally, in order to assess the relationship between CIB and CA, the assessment of the accuracy of the copy independently from the misplacement of the copy appears to be indispensable.

CLOSING-IN BEHAVIOUR IN NEUROPATHOLOGY

CIB has been observed in patients affected by different brain diseases (dementia, cerebral stroke, carbon monoxide poisoning, corticobasal degeneration, encephalitis, and epilepsy), and associated with different cognitive impairments (see Table 2.2 for a summary of single case studies). Moreover, as for CA, CIB has been reported following a variety of focal brain lesions. Mayer Gross (1935, p. 65) examined the brain of one of his patients with CIB post-mortem and found “areas of deep softening in the lower part of the left parietal lobe [...] and corpus callosum”. Further studies (Critchley, 1953; Kwon et al., 2002; Suzuki et al., 2003) confirmed the appearance of CIB after damage in the parietal lobe**,** supporting the view of CIB as a manifestation of CA. However, CIB has also been found as a consequence of frontal dysfunctions (Conson et al., 2009; Septien, Giroud, Sautreaux, & Dumas, 1992). Moreover, a SPECT study (Midorikawa, Fukatsu, & Takahata, 1996) demonstrated reduced activity in both the parieto-occipital and the frontal areas in a patient with AD, who showed both CIB and CA in constructional tasks.

In relation to hemispheric side of lesion, CIB has been reported after right hemisphere stroke (Grossi et al., 1996) and has been related to activity of the right hemisphere measured with electroencephalogram (Pavan, 1966). On the other hand, the phenomenon was not observed in a sample of 100 patients with right hemisphere stroke and left unilateral spatial neglect in graphic copying tasks (Seki et al., 2000). Moreover, CIB has also been found after bilateral lesions of the parietal hemisphere (Suzuki et al., 2003), and the common appearance of CIB in dementia suggests that CIB can appear as a consequence of widespread lesions. In support of this, a study, which assessed electroencephalographical activity of patients with dementia failed to find any significant difference between patients with and without CIB (Kwak, 2004). Overall, the anatomical localization of CIB appears to be a difficult aim, though more standardised behavioural approaches to the symptom can presumably only increase the chances of identifying specific neuroanatomical correlates.

Another aspect, which emerges from single case studies, is that the phenomenon has been found to be associated with a wide variety of cognitive deficits (see Table 2.2). CIB has been found in patients with impairment in memory, recognition of the body part, writing, arithmetic calculation, reading, visuospatial skills, and executive functions. CIB has also been found in association with utilization behaviour (Conson et a., 2009) and grasping reflex (De Ajuriaguerra et al., 1960; Kwon et al., 2002), echolalia and echopraxia (Muncie, 1938). Moreover, although some patients do not able recognize their pathological tendency to approach the model (Muncie, 1938), many patients do demonstrate awareness of the abnormality of their behaviour (Mayer Gross, 1935; De Ajuriaguerra et al., 1949). Therefore, CIB is often accompanied by a sense of frustration, due to the awareness of difficulties in completing the task properly.

A specific association between the phenomenon and cognitive impairments in another domain is difficult to infer from the single case studies presented in the literature of CIB. The only constant association described in the different studies is that between CIB and CA, which has been suggested to be a possible confounding factor in the assessment of the phenomenon; and the scoring procedures used to assess CIB might play an important role in emphasising and strengthening this relationship.

Table 2.2. Summary of the singles case studies on CIB.

Author(s)	Diagnosis	CA	Memory Deficit	Visuospatial impairment	Ideomotor Apraxia	Finger Agnosia	Right/Left disturbances	Visual agnosia	Agraphia	Acalculia	Other associated cognitive deficits
Muncie, 1938	Dementia	√	√	-	x	√	x	x	√	-	Echolalia, echopraxia perseverations, difficulty in understanding proverbs
Lhermitte and Mouzon, 1941	Stroke in left occipital lobe	√	x	√	x	√	x	x	x	x	
Stengel and Vienna, 1944	Eclampsia Epilepsy	√	x	√	x	√	√	x	√	√	Simulanagnosia, difficulty in localization of object in space
De Ajuriaguerra et al., 1949	Carbon monoxide intoxication	√	√	√	√	√	x	x	√	√	
De Renzi, 1959	Alzheimer's Disease	√	√	x	x	√	√	x	√	√	Alexia, hemianopia
Pavan, 1966	Pre-senile dementia	√	x	x	x	x	√	x	√	x	Dressing apraxia, topographic disorientation
Kuroiwa et al., 1967	Carbon monoxide intoxication	√	√	-	-	x	x	√	√	√	Alexia
Cipollotti and Denes, 1987	Arteriosclerosis	√	√	-	√	-	x	-	√	-	
Grossi et al, 1996	Right hemisphere stroke	√	x	√	-	-	-	-	-	-	
Kwon et al., 2002	Corticobasal degeneration	√	√	-	√	-	-	-	√	-	Bradykinesia, dressing apraxia, poor phonemic fluency, grasp reflex
Suzuki et al., 2003	Bilateral parietal lobe atrophy	√	√	√	-	-	-	x	√	-	
Conson et al., 2009	Corticobasal degeneration	√	x	√	√	-	-	-	-	-	Poor inhibition of automatic response, Utilization behaviour

√ symptom present; x symptom absent; - symptom not reported

Frequency and severity of CIB

A few group studies investigated the frequency and severity of CIB (for graphic copying) in different pathological conditions (see Table 2.3). Direct comparisons between studies are complicated by differences in tasks and qualitative criteria for the classification of CIB, but several broad patterns can be discerned.

First, the incidence of this symptom is low in patients with focal cerebral infarcts (7.5%) or mild dementia (6%), but rises dramatically with the progression of dementia through moderate (42%) and severe (61%) stages (estimates from Gainotti, 1972; see also De Ajuriaguerra et al., 1960). Moreover, the frequency of certain types of CIB, such as the tendency to draw directly on the top of the model, appears to be more sensitive to the dementia severity and increases in severe dementia (Gainotti, 1972) (see Figure 2, right panel).

Second, the severity of CIB tracks a parallel course, with the deterioration in the quality of the reproduction, progressing from encroachment of the copy on the model, to overlap between the copy and the model, with unrecognisable scrawling over the model as the end-state (Gainotti, 1972). Third, CIB is common in AD (Ober et al., 1991; Rouleau et al., 1996; Spinnler and Della Sala, 1988), and more prevalent than in Vascular dementia (VaD) (Gainotti et al., 1992; Kwak et al., 2002; Gainotti et al., 1998; Grossi et al., 1978; Midorikawa et al., 1996). CIB has been found in a higher frequency in AD than VaD, when AD patients were more impaired in overall severity of dementia and constructional abilities (Kwak, 2004) or visuospatial working memory (Gainotti et al., 1998) than VaD. However, a higher frequency of CIB in AD was also found when these groups of patients were matched for age, education, dementia severity, and when they showed similar levels of executive functions, working memory, visuospatial and constructional abilities (Gainotti et al., 1992). On the other hand, a recent study (Chin et al., 2005) did not confirm the higher frequency of CIB in AD than VaD. In this study, AD and VaD patients were matched for demographic characteristics, overall dementia severity, and constructional abilities, and no significant difference was found in the frequency of CIB between the two groups. Moreover, in contrast to a previous study (Kwak, 2004), in this sample CIB was not correlated with the overall dementia severity, but solely with the performance in constructional task.

Although the sensitivity of CIB to AD may not be especially high, at least in the mild stages of the disease, its specificity for AD has been estimated at around 80% compared with vascular and subcortical vascular dementia (Gainotti et al, 1998; Kwak, 2004), suggesting that CIB might be a good tool for the differential diagnosis of AD (Kwak, 2004). A principled understanding of the mechanisms underlying CIB might thus be informative regarding the specific cognitive character of AD. Finally, it is worth noting that the phenomenon has also been observed in patients with FTD, and preliminary evidence suggests that the phenomenon might be as common in this group of patients as in AD (Ambron, McIntosh, Allaria, & Della Sala, 2009; Gasparini et al., 2008). However, since this phenomenon has just been noted, in passing, and assessed as one CA manifestation across a variety of CA errors (such as perseverations, omissions, rotations, etc.), this evidence needs to be and systematically investigated in larger samples of patients.

Table 2.3. Studies on CIB in patients groups

Author(s)	Task	CIB scoring procedure	Sample	CIB frequencies
De Ajuriaguerra et al., 1960	Graphic copying tasks	Presence/ absence of CIB	21 patients with dementia (probable AD)	*7 (33%)*
Piercy et al., 1960	Copy of a cube	Presence/ absence of CIB (superimposed/ overlap)	18 left brain damage 24 right brain damage	*6 (33%)* *2(8%)*
Gainotti & Tiacci, 1970	Arrigoni & de Renzi's (1964) copying task	Presence/ absence of CIB (overlap)	100 left brain damage 100 right brain damage	*5 (5%)* *10 (10%)*
Gainotti, 1972	Arrigoni & de Renzi's (1964) copying task	CIB types: Scrawl Contour Transport Near Unsettled lines	132 patients with dementia: - 67 mild - 42 moderate - 23 severe 200 focal brain damage patients	*36(27%)* *- 4 (6%)* *- 18 (43%)* *- 14 (60%)* *15(7%)*
Grossi et al., 1978	Arrigoni & de Renzi's (1964) copying task	Presence/ absence of CIB	21 AD 11 Senile dementia 20 Huntington's chorea 25 Multi infarct dementia 27 Cerebral atrophy 4 Pick type dementia 2 Normal pressure hydrocephalus 108 normal adults	*8 (38%)* *2(19%)* *0* *0* *0* *0* *0* *0*
Gainotti et al., 1992	Graphic copying and copy with landmarks of star, cube, house)	Standard and variant CIB	41 AD 34 VaD 50 older adults	*9(22%)* *2 (6%)* *0*
Rouleau et al., 1996	Clock copying task	Presence/ absence of CIB (part of the stimulus-bound response dimension)	33 AD	*2 (6%)*
Gainotti et al., 1998	Graphic copying of star, cube, house	Presence/ absence of CIB (tendency to copy near or adherent or on the top of the model)	49 AD 14 progressive supranuclear palsy 26 depressive pseudodementia 35 Parkinson disease +dementia 43 multi-infarct dementia 30 older adults	*15 (31%)* *1 (7%)* *1 (4%)* *0* *3 (7%)* *0*
Gragnaniello et al., 1998	Overlapped pentagons	Presence/ absence of CIB	37 AD	*6 (16 %)*
Lorenzo-Otero, 2001	9 shapes (2D, 3D and made up of lines)	Presence/ absence of CIB (tendency to copy near or on the top of the model)	82 AD 26 older adults	25 (30%) 0
Kwak, 2004	Luria's figure	CIB types: Overlap Adherent Near	98 AD 48 Subcortical VaD 22 older adults 30 young adults	*41 (42%)* *11 22%* *2 (9% near)* *0*
Lee et al., 2004	Luria's figure	Presence/ absence of CIB (slop of the drawing) vs. controls	36 patients with AD	*13(36%)*
Chin et al., 2005	Luria's figure	Presence/ absence of CIB (slop of the drawing) in relation to controls	55 AD 39 VaD 38 Older Adults	18 (33%) 10 (26%)
Gasparini et al., 2008	10 copying tasks of Benton visual retention test	Presence/ absence of CIB	41 AD 15 FTD (fronto-variant)	1 (2%) 1 (7%)

CLOSING-IN BEHAVIOUR ACROSS THE LIFE SPAN: NORMAL DEVELOPMENT AND NORMAL AGING

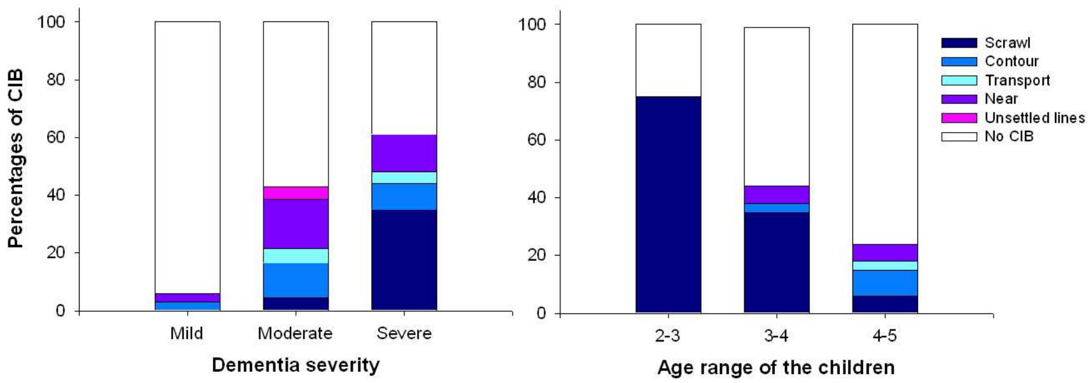
If associated with brain damage, CIB is considered a pathological symptom. Yet similar phenomena can be observed in early childhood. Prudhommeau (1947) identified this tendency in the development of graphic abilities, and Wallon and Lurçat (1957) similarly emphasised an “attraction to what already exists” (p. 276) in young children and in children with “mental deficiencies”.

Although some authors had drawn parallels between the development of graphic abilities in childhood, and their deterioration in dementia (e.g., De Ajuriaguerra et al., 1960; Muncie, 1938), Mendilaharsu, Delfino de Cultelli, and Sapriza de Correa (1970) were the first to study children’s copying specifically with regard to Mayer Gross’ category of CIB (1935). Copying of geometric figures was assessed in 386 children, aged between two and seven years. Three main stages in the evolution of performance were identified: colonization of the model (scrawling over the model), utilisation of the model (drawing connected to or bounding the model), and separation of the copy from the model. Scrawling over the model was universal in children under two-and-a-half years, and declined thereafter (disappearing by the age of four), whereas utilisation of the model had its peak at around three-and-a-half years of age. By the middle of the fifth year, all children had achieved separation of the copy from the model. The parallel with adult CIB, drawn by these authors, implies that its appearance in association with brain damage might represent regression to more primitive stages of graphic development (see also De Ajuriaguerra et al., 1960).

A similar developmental trajectory was described by Gainotti (1972), who assessed 118 children, aged from two to six years, on the graphic copying battery of Arrigoni and De Renzi (1964). The typology employed by Gainotti was conceptually closed to that of Mendilaharsu et al. (1970), but distinguished four (rather than two) sub-types of CIB: scrawling on the model; overlapping or bounding the model; extending lines from the model to the surrounding space; copying near or adherent to the model. The findings were broadly consistent with the patterns reported by Mendilharsu et al. (1970): scrawling on the model was common (75%) in two-year-olds, decreasingly frequently in three (35.5%) and four-year-olds (6%), and absent by the age of five; whilst connected, overlapping or bounded copies were most frequent in the three year-old group (25.8%, collapsed across Gainotti's second and third subtypes). The fourth, 'near or adherent', subtype was first observed in three-year-old (6.5%), had its highest incidence in four year old (12.1%), and was observed occasionally amongst five-year-old children (7.7%).

A particularly interesting aspect of Gainotti's (1972) study is that similar tasks and criteria to define the phenomenon were used to assess CIB in children and in patients with dementia (see previous section). Therefore, the author was able to directly compare the appearance of CIB in the two groups, showing that the progression of CIB with dementia severity showed a striking reversal pattern of the developmental course in children, with mainly near-or-adherent copying in mild dementia progressing to a severe end-state of scrawling on the model (see Figure 2.6). These superficial similarities do not necessarily imply that common factors underlie CIB in development and dementia, but such a possibility would be consistent with the notion that primitive behavioural patterns may reappear in neuropathology due to the disruption of higher executive mechanisms (De Ajuriaguerra et al, 1960; Gregory, 2001).

Figure 2.6. Percentages of CIB types in relation to the age of the children (left panel) and dementia severity (right panel). Diagram generated from data reported by Gainotti (1972)



A mild form of CIB has also been observed at the other end of the life span: among the healthy elderly. Kwak (2004) tested 22 older people (Mean age=67.30;

SD = 8.46) and found two participants (9%) who tended to copy near to the model. This tendency was not observed in any of the 30 young controls. The authors suggested that the *near type* of CIB could be related to the physiological decline of the aging process, which primarily involves attention and executive functions. The more severe, *overlap* CIB has never been observed in healthy participants, and may be a more specific pathological symptom. Similar results were obtained by Lee et al (2004), who found that older individuals (mean age = 68.6; *SD* = 8.1) showed an upward slope in drawing Luria's figure, suggesting a mild tendency to draw toward the model at the top edge of the page. However, since the position of the model was not manipulated in this study, it is not possible to conclude definitely that the upward slope represented a migration toward the model, rather than a less specific upward bias. These findings suggest that a mild form of CIB, although not common, might appear as a consequence of the aging process. However, further investigations need to be addressed to systematically explore the phenomenon in this population.

CLOSING-IN BEHAVIOUR INTERPRETATIONS

As noted, the first interpretation of CIB dates back to Mayer Gross (1935), who explained CIB as a symptom of CA. The author considered CA as a general disorder of the hand and fingers' activity in the space and CIB as a specific manifestation of this disturbance. Therefore, CIB was interpreted as "an injury in the space extension" (p.1211), which caused the tendency of hands and fingers to move toward anything which could fill the space. This tendency was interpreted as a "primary biological protective mechanism" to overcome the "fear of empty space" (p.1211). The first two decades after Mayer Gross' explanation of CIB have been characterized mostly by single case studies in which the authors attempted to describe and clarify the nature of CIB, implementing a variety of idiosyncratic interpretations, expressed in the language of the time, but unlikely to fit well with the contemporary cognitive framework. Therefore, CIB has been interpreted variously: as the reappearance of the primitive conception of the relationship between objects, based on proximity alone (Stengel & Vienna, 1944); as a symptom of the confusion between personal and extra personal space (Critchley, 1935); and as an inability to act in open space (De Renzi, 1959).

Besides these idiosyncratic hypotheses regarding the origins of CIB, two main trends developed in the literature to explain CIB: the compensation and the attraction hypotheses. The compensation hypothesis was first championed by Muncie (1938), who explained CIB as related to the difficulty in symbolic abstraction from a concrete model (see section on Early reports). Although his theoretical interpretation might be too ambitious and broadly-applied (uniting three very different behaviours as manifestations of the same symptom), this theory led the way in the future development of the 'compensation' hypothesis.

This hypothesis was later defined and stated clearly by different authors (Kwon et al., 2002; Lee at al., 2004) and suggests that the cognitive origins of CIB are related to visuospatial and/or working memory deficits. This account proposes that patients with CIB have difficulty in correctly perceiving and analysing the model; its elements and their spatial relationships; and/or in creating and maintaining in memory, an abstract representation of the model. The patient would perform close to the model in order to reduce the visual distance between the model and the space of copying. This hypothesis considers CIB as *compensatory strategy* to overcome visuospatial or working memory[1] deficits. In support of this view, Grossi et al. (1996) described the appearance of CIB in a patient with right hemisphere stroke and severe visuospatial impairment. The authors interpreted the appearance of CIB in this patient as an effect of the visuospatial impairment. Therefore, they suggested that the patient performed the graphic copying close to the model in order to reduce the visual distance between the model and the copy. This hypothesis has been echoed in a recent study (Ogawa & Inui, 2009), suggesting that CIB might be caused by a deficit in the ability to create an abstract representation of the model. Therefore the patient might convert the graphic copying into a tracking task in order to compensate for his deficit in this way. In this study, the authors recorded the brain activation of 28 young adults using functional magnetic resonance imaging (fMRI) technique during graphic copying and tracking tasks. The results showed differentially greater activation of the parietal-premotor and mesial motor areas, as well as in the occipital

[1] The term working memory used in Lee et al. (2004) is defined as the ability to hold information in memory and does not really involve any modification of the representation, as described in the text. Although the term "short term memory" might be, therefore, more appropriate, for the sake of consistency with the original terminology used by the authors, the term 'working memory' will be used here and in the other sections of the present thesis.

cortex, and a specific increase of the activity of the intra-parietal sulcus during graphic copying task. Therefore, the authors suggested that intra-parietal sulcus might be involved in coordinate transformation for graphic copying. Damage in this area might thus precipitate CIB. This last hypothesis is very speculative, and further studies need to test this account.

The attraction hypothesis dates back to studies which explored CIB in dementia (Vereecken, 1958; De Ajuriaguerra et al., 1960; Gainotti, 1972). Based on the observation of the common appearance and characteristics of the phenomenon in patients with dementia and in pre-school children, different authors posited that CIB in dementia represents the re-emergence of a primitive magnetic behaviour. Vereecken (1958) interpreted CIB as an optical manifestation of a grasping reflex characterized by the attraction of the hand toward the stimulus presented in the visual field. In a similar way, De Ajuriaguerra et al. (1960) pointed out the appearance of CIB in conjunction with the grasping reflex and adherence of the gaze in severe dementia, as evidence of the reappearance of a “primitive sensory-motor organization” (p. 434) during the global cognitive degeneration of dementia. Gainotti (1972) expanded this hypothesis and suggested that CIB like other forms of automatic behaviour, such as grasping, sucking reflexes, echolalia, and ecopraxia, is a common behaviour during the fist stage of human life. They then disappear during development, thanks to inhibition from the higher cortical areas of cognition. This inhibition mechanism decreases with the cognitive decline of the dementia process, causing the reappearance of these “reflex patterns of behaviour” (p. 434).

In line with this *primitive behaviour hypothesis*, other authors (Conson et al., 2009) proposed the use of competitive tropisms theory introduced by Denny-Brown (Denny-Brown, 1956; 1958; Denny-Brown & Chambers, 1958) as a possible interpretation of CIB. Denny-Brown competitive tropisms theory was based on the observation that two classes of motor responses to the stimuli present in the environment occur in brain-damage patients (and monkeys with ablation of parietal or frontal lobes). Patients with damage to the parietal lobe showed motor behaviour characterized by the “avoiding responses” (p.298). On the contrary, lesions involving the frontal lobes produced approach behaviours such as instinctive grasping and palpations. These primitive tropisms involved both tactile and visual modalities and re-emerged as an effect of damage to specific brain areas. As Conson et al. (2009) proposed, CIB might be considered a manifestation of the positive approach tropism, released by damage to the frontal lobes. This hypothesis, as formulated, does not readily account for CIB in patients with damage outside the frontal lobes. However, it is possible that CIB in patients with frontal damage might have a diverse nature from CIB as consequence of damage to different brain areas.

The attraction account of CIB has been recently specified in more detail (Kwon et al., 2002; Lee at al., 2004). This account posits that CIB is a primitive default behaviour, which is characterized by the attraction of the active hand toward the focus of attention. Support to this hypothesis derives from the assessment of eye movement during a graphic copying task of patients with AD (Midorikawa et al., 1996). Patients who showed the tendency to overlap the copy with the model show a locking on fixation, while patients who performed the copy near or adherent to the model showed a wandering of fixation type of eye movement. Moreover, recent studies further specified this account suggesting that the release of this primitive behaviour might be due to reduced attentional and/or executive resources (Conson et al., 2009; Kwon et al., 2002, Lee at al., 2004).

A few studies have attempted to test experimentally between these two hypotheses of CIB. Kwon et al. (2002) tested the compensation hypothesis in a patient with corticobasal degeneration, manipulating the complexity of the gesture to be imitated (simple vs. complex), the position of the examiner (across vs. lateral) and the hand to be used to perform the gesture (right or left). This manipulation aimed to increased the load of visuospatial abilities and working memory, which have been posited to be higher in copying more complex gestures at a higher distance between the positions of the model (across vs. lateral position of the examiner). The author found that while the accuracy of the gesture decreased in copying complex gestures, the frequency and the severity of CIB did not significantly increase. Moreover, there was no significant difference between the positions in which the model-gesture was performed. These results have been interpreted in favour of the attraction hypothesis, suggesting that CIB is a sort of primitive “visual grasp” (p. 1474) which remerges from the lack of inhibition caused by a frontal lobe dysfunction. In other words, the lack of inhibition would cause the emergence of a primitive manual tendency to act toward the focus of attention.

Lee et al. (2004) adopted a similar experimental manipulation and rationale to test CIB in AD in the graphic copying domain. In order to primarily test the compensation hypothesis, the author manipulated the complexity of the stimulus, (straight line copying task, three versions of Luria's figure of increasing complexity) and the distance between the model and the copy (5, 10 and 15 cm). Unlike Kwon et al.'s (2002) methodology, the position of the model was not manipulated in this study, and the model was presented only at the top of the sheet of paper. The result replicated Kwon et al.'s (2002) observations of a lack of significant effect of distance on CIB. However, CIB significantly increased with the complexity of the model. The authors interpreted this result as evidence against the attraction hypothesis. In their understanding, the attraction hypothesis would predict the appearance of this primitive behaviour when the position of the model is close to the copy space, independent from the complexity of the copying task. Therefore, the authors suggested that the compensation hypothesis would predict the increase of CIB in copying more complex shapes and with a bigger gap between copying and model space. This lack of effect was explained by the weak manipulation of the distance, since a modulation of CIB appeared, but did not reach a significant level.

Finally, Conson et al. (2009) explored the nature of CIB and its relationship with CA in a patient with corticobasal degeneration in three experiments. In the first experiment, the authors manipulated the complexity of the figure to be copied (simple: 2D pictures, complex: 3D pictures) and controlled the starting point. The result of this experiment replicated Kwon et al.'s results (2002) as the frequency of CIB did not increase with the complexity of the task. The authors interpreted this result as supportive of the idea of the primitive and automatic nature of CIB, which might be exhibited independently from the complexity of the task, rather than as a manifestation of working memory or visuospatial alterations. In the second experiment, the patient performed graphic copying and drawing of bi-dimensional pictures. Her performance was more accurate in the drawing on command condition compared to the copying task. This evidence further supported the primitive and automatic nature of CIB and contrasted with the compensation hypothesis, which postulates a relationship between CIB and visuospatial and working memory processing. In the final experiment, the patient was presented with a copying task consisting of the copy of a line printed inside one circle. The patient was asked to reproduce the position of the line in a circle printed next to the original model. In this task the authors manipulated both the position of the model-circle (placed either on the top, bottom, right, or left, of the original model) and the position of the line inside the model-circle, which varied assuming all the possible positions of the numbers in the clock. The performance in this task was markedly influenced by the position of the model-circle and it was characterized by a "spatial transposition" (p. 286) of the lines toward the location of the model. Therefore, the author concluded that CIB is the attraction of an action toward the focus of attention and this misplacement of the graphic copying influences the accuracy, altering the spatial relationship between the different elements of the copy drawing.

Although direct comparison between these studies is difficult since different tasks, methodologies and patients were used, some considerations can be attempted. First, as suggested in previous sections, the inconsistency of the results regarding the effect of complexity might be related to the different neuropathologies affecting the patients examined. Therefore, in Lee et al's (2004) study, the sample was composed of patients with AD, wheras in both single case studies (Conson et al., 2009, Kwon et al., 2002) a frontal lobe dysfunction was observed. Second, the effect of complexity might not be the definitive manipulation to distinguish between the two hypotheses. Although the compensation hypothesis would predict the increase of CIB with higher visuospatial and working memory requirements of the copying task, it is not entirely clear that the attraction hypothesis would not predict a similar pattern. Taking into account the further specification of the attraction hypothesis, which proposes that the release of CIB might be related to attention and/or executive deficits, then this tendency might well be affected by the complexity of the task, because of the greater demands placed on attention. Therefore, both attraction and compensation hypothesis might predict the increase of CIB with the complexity, making this a poor experimental manipulation to test between the two accounts.

Similar considerations can be drawn in relation to the manipulation of the distance between the copy and the model as crucial factors to distinguish between the two competing interpretations of CIB. The attraction hypothesis predicts the appearance of this primitive manual attraction toward any relevant stimulus; therefore the manipulation of the distance is predicted not to have an effect on CIB. However, further specifications of this hypothesis hinted at the role of attention and executive functions promoting the appearance of this behaviour. Therefore, if this hypothesis is correct, CIB is expected to increase with increasing distance between the model and the copy. If the model is placed far from the copy in the working space, the attention switching and monitoring requirements of the copying task will increase, with the consequent expectation of an increase of CIB. In the same way, the compensation hypothesis predicts the increase of CIB when the model is placed at a longer distance from the copying space, since more working memory ability is required.

To conclude, contrasting results supporting either one of two competing hypothesis of CIB appeared in the literature, highlighting the importance of developing specific manipulations, which provide clear tests between the compensation and the attraction hypothesis. Moreover, a further direction in the study of CIB would be to assess the relationship between CIB and the different cognitive functions posited to be involved with this phenomenon. This would represent a further investigation of the two accounts of CIB, since the attraction hypothesis suggests the involvement of attention and/or executive functions in the appearance of CIB, while the compensation hypothesis considers CIB to be related more strongly to visuospatial and working memory deficits.

CONCLUSION

This literature review aimed to explore the studies on CIB highlighting the difficulties in defining and assessing the phenomenon. As for CA, the literature of CIB is characterised by the great variety of studies, which often reports contrasting results about the nature and the characteristics of this phenomenon. This is mostly caused by the ambiguity and confusion in the definition of the phenomenon and of different methodologies applied to assess CIB. A constant trade-off between qualitative and quantitative assessments of the phenomenon emerged in the present literature review. Although the dilemma between a more rigorous assessment of the phenomenon and the importance of a detailed qualitative description of the different manifestations of CIB appears to be difficult to solve, a more systematic approach in the study of CIB should be pursued. This approach should be devoted to explore some key questions which emerged from CIB literature.

First, the relationship between CA and CIB should be further explored. Although the phenomenon has been classically considered as a manifestation of CA (Critchley, 1953), the appearance of CIB in other cognitive tasks (such as gesture imitation and writing) suggests that CIB might be a more general phenomenon. Second, the different manifestations of CIB, such as the tendency to perform the copy abnormally close to the model (near CIB) and the tendency to perform the copy on the top of the model (Overlap CIB) have been assumed to lie on a continuum of severity (Gainotti, 1972). However, it is still uncertain if these CIB types share a similar cognitive nature. Third, the common appearance of CIB in AD suggests that this symptom may be highly informative regarding the cognitive basis of AD. However, it is still in doubt if the appearance of CIB in AD and other forms of dementia share common characteristics and cognitive nature, or if CIB represents an analogous symptom caused by different cognitive deficits. Moreover, the general appearance of CIB in patients with dementia and in pre-school children should be further investigated. In particular, it should be explored if the superficial similarities noted in the appearance of CIB in these two different groups reflect the presence of a common cognitive nature of CIB. In general, a new direction in the literature of CIB should be developed toward the assessment of the cognitive basis of CIB.

The present thesis aims to concentrate on these key areas of investigation. First, the cognitive basis of CIB, and the relationship between CIB and CA, will be explored in patients with dementia (see Chapter 3, 4, and 5). Second, CIB will be assessed in children, seeking clues as to its cognitive basis, and allowing comparison with the earlier clinical results (see Chapter 6, 7, and 8). Finally, a series of experiments will be reported that assess whether closing-in-like behaviour can be induced in normal healthy adults under appropriate tasks conditions (see Chapter 9 and 10).

SECTION 1

EXPLORING CLOSING-IN BEHAVIOUR IN PATIENTS WITH DEMENTIA

CHAPTER 3
A large scale retrospective study of Closing-in behaviour in dementia.

INTRODUCTION

As described in the Chapter 2, CIB is the tendency, during copying tasks, to perform the copy very close to, or even on top of the model (Mayer Gross, 1935). It is commonly believed that such ‘overlap’ behaviours differ only in degree from the propensity to perform very near to the model without overlap (Gainotti, 1972). Both forms of CIB are observed in patients with dementia, being more common with increasing severity of cognitive impairment (De Ajuriaguerra et al., 1960; Gainotti, 1972; Ober et al., 1991). Gainotti (1972) also found that overlap-type CIB becomes increasingly frequent relative to near-type CIB with increasing cognitive impairment. In a sample of 132 patients with dementia, near-CIB appeared in 2 patients from a total of 67 (3%) patients with mild dementia, in 7 out of 42 (17%) patients with moderate dementia and in 3 of 23 (13%) patients with severe dementia. None of the patients with mild dementia performed the copy on the top of the model, while 2 (5%) and 8 (35%) of the patients with moderate and severe dementia showed such overlap-CIB. This evidence supported the idea that these manifestations of CIB lie on a continuum of severity.

Among the different types of dementia, CIB has been most commonly associated with AD (Gainotti et al., 1992, 1998; Grossi et al., 1978; Kwak et al., 2002**;** Spinnler and Della Sala, 1988). Grossi et al. (1978) assessed the frequency of CIB in patients with different neuropathologies (Huntington’s chorea, cerebral atrophy, normal pressure hydroencephalus) and forms of dementia (AD, senile dementia, multi-infarct dementia, and Pick type dementia). CIB was found in 8 patients from a total of 21 (38%) with AD, and in 2 from a sample of 11 (19%) patients with senile dementia. Gainotti et al. (1998) obtained analogous results, finding a higher frequency of CIB in AD (31%) than in multi-infarct dementia (6%), progressive supranuclear palsy (7%), and depressive pseudo dementia (3%). Several studies showed that the frequency of CIB is higher in AD than in dementia of vascular aetiology (Gainotti et al., 1992; Kwak et al., 2002). However, a recent study, applying a quantitative criterion for the assessment of CIB and matching the groups for severity of cognitive decline, suggests that the phenomenon might be equally common in AD and VaD (Chin et al., 2005). CIB has also been observed in FTD (Gasparini et al., 2008), however, the frequency and characteristics of CIB have never been systematically investigated in this cohort.

CIB leads to impairments in copying tasks, and has long been classed as a form of CA (Critchley, 1953; Grossi & Trojano, 1999; Mayer Gross, 1935), with the implication that its functional basis may be impaired visuospatial cognition. An alternative view is that CIB represents a primitive behaviour in which the acting hand is attracted toward the focus of visual attention (Gainotti, 1972; see also Chapter 4). This attraction hypothesis has recently gained experimental support from small-group and single-case studies of patients with AD (Lee et al., 2004; see also Chapter 4) and corticobasal degeneration (Conson et al., 2009; Kwon et al., 2002). The release of this primitive behaviour may require a reduction of attentional resources, implying that CIB may be a clinical indicator of attentional deficits in dementia (Conson et al., 2009; Kwon et al., 2002).

The present study represents the largest survey to date of CIB in patients with AD (n = 797), and incorporates the first longitudinal analysis of this symptom, in a subset of this cohort (n = 132). Moreover, this study represents the first systematic investigation of CIB in patients with FTD (n = 56). The key data of the present study derive from a retrospective analysis of the graphic copying component of an extensive neuropsychological battery. This large dataset allows the assessment of the frequency of the different forms of CA (moderate and severe) and CIB (near and overlap) in relation to severity of dementia, and an exploration of the cognitive factors predicting CIB, using both cross-sectional and longitudinal approaches.

MATERIAL AND METHODS

Patient cohort

The neuropsychological records of 797 patients with a diagnosis of probable AD according to the formal criteria of the NINCDS-ADRDA (McKhann et al., 1984) were reviewed. These records were kept in the archive of the neurological ward of St Paolo Hospital (Milan). The patients (281 male, 516 female) had a median age of 78 (range 45-98), a median of 5 years' education (range 2-20), and a median duration of disease at testing of 36 months (range: 1-192). Longitudinal data were available for 132 patients (59 male, 73 female), who had undergone a second assessment after an average of 1.3 years (SD = 0.83). This subset had a median age of 76 years (range: 57-92) at first assessment, a median of 5 years of education (range 2-18), and a median duration of disease at first testing of 24 months (range 4-84). By comparison to the subgroup of patients not retested (n = 665), the longitudinal subgroup was significantly younger (median 76 vs. 79 years, z = -3.85, p < .001) with a higher proportion of males (44.7% vs. 33.4%, z = -2.48, p = .013), but well-matched for years of education (median 5 for both subgroups, z = -.099, p = .921).

Finally, the records of 56 patients (29 male, 27 female) with a diagnosis of FTD (The Lund and Manchester Groups, 1994) were also re-collected. FTD patients had a median age of 70 (range 41-88), a median of 5 years of education (range 0-19), and a median duration of the disease of 24 months (range 7-72). This last cohort showed a similar duration of the disease as the AD group (z = -1.27, p = .20), however a significant difference between the two groups of patients was found for age (z = -7.14, p < .001), education (z = -2.19, p = .029), and severity of dementia measured by the overall MODA score (z = -2.56, p = .010). For this reason, the two groups of patients were considered independently in the data analysis.

Neuropsychological assessment

Each assessment involved completion of the MODA (Milan Overall Dementia Assessment), a neuropsychological battery with 11 sub-tests (see Appendix 3a). These included interview-based assessments of *orientation* (score range 0-35) and *autonomy* (score range 0-15), which were weighted equally into a single Behavioural subscale. *Verbal intelligence* was assessed by questions requiring the detection of semantic differences (e.g., truck vs. coach) and comprehension of common proverbs (e.g., one swallow does not make a summer) (score range 0-10). A *Digit Cancellation* test (score range 0-10) required patients to search for ten instances of a target (number 5) among 100 distractors (other digits from 0-9) for 45 seconds. A preliminary practice search in a simplified array established that the patient could meet the minimum visuospatial requirements for target recognition.

Moreover, since the search target was a single, highly familiar symbol, the memory load was very low for this task. Accordingly, although this task certainly requires multiple cognitive abilities, it has been shown to load heavily upon attention, relative to other cognitive domains (Spinnler, 1991), and has been used previously as a specific measure of attention in patients with AD (e.g. Della Sala, Laiacona, Spinnler, & Ubezio, 1992). *Verbal Fluency* (score range 0-5) required the generation of animal names for two minutes. *Luria's Reversal Learning* (score range 0-5) required patients to reverse a learned response pairing (palm vs. fist) in a gesture imitation task. *Prose Memory* (score range 0-8) required recall of a meaningful story. *Finger Identification* (score range 0-5) required patients to identify unseen touches to their fingers by reference to a model. The *Token Test* required the comprehension and execution of verbal instructions using coloured tokens. *Street's Completion* test (score range 0-3) required the identification of degraded black-and-white pictures. Finally, *Figure Copying* required graphic reproduction of three geometrical shapes presented in a constant order (square, diamond, and multipart figure); the original score recorded for this test (range 0-3) contributed to the calculation of the overall MODA score. However, for the purposes of regression analyses, the original score was replaced by a new rating, which scored copy quality independently of proximity to the model (see Scoring Methods, below).

The MODA has published norms from 217 healthy subjects (age range 25- 85 years; educational range 3-17 years), allowing each patient's total score to be adjusted for age and education (Brazzelli, Capitani, Della Sala, Spinnler, & Zuffi, 1994). The adjusted score is scaled from 0-100, with scores above 89.0 considered normal (inner tolerance limit), and scores below 85.5 pathological (outer tolerance limit). Three levels of AD severity were defined by Brazzelli et al. (1994): severe (MODA $\leq$ 49), moderate (49 < MODA < 85.5) and borderline (85.5 $\geq$ MODA $\leq$ 89). The median adjusted MODA score of the total cohort of AD was 70 (range 10-89). The median adjusted MODA score of the longitudinal sample of AD was 78 (range 38-89) at the first assessment and 66 (range 14-88) at the second. The decline in performance between first and second assessments was highly significant (z = -9.61, p < .001). Finally, the median adjusted MODA score of the FTD patients was 76 (range 20-89)

Because of the retrospective nature of this study, informed consent from the patients was not required. Instead, ethical approval for the review was obtained from the medical ethics committee responsible of the neurological ward of St Paolo Hospital (Milan), guarding the archive.

Scoring Methods

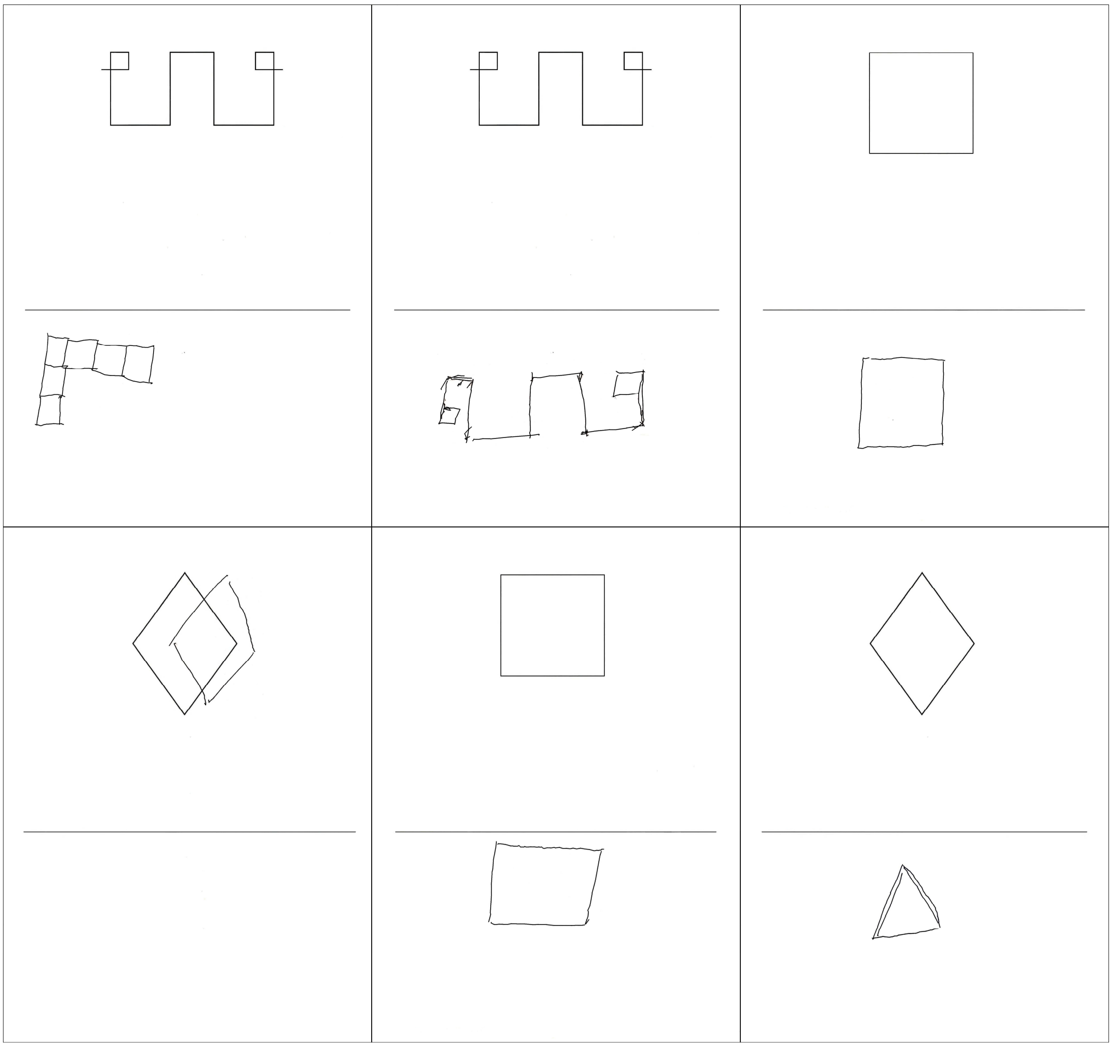
Demographic details and MODA scores were transcribed from the archives. Each subtest score was expressed as a percentage of the maximum possible, with the exception of the Figure Copying task. The original sheets for the Figure Copying task were re-scored according to criteria that attempted to separate CIB (proximity of the copy to the model) from other aspects of copy quality. In the Figure Copying subtest of the MODA, the copy space is clearly defined by a horizontal line printed in the centre of the sheet (see Figure 3.1), and the examiner indicates the copy space whilst instructing the patient to perform the copy in the lower half of the sheet. For each picture, CIB was categorised according to the following criteria (see Figure 3.1, bottom row, for examples):

- **Overlap-CIB**: at least part of the copy invades the model's space in the top half of the sheet.
- **Near-CIB**: the copy comes very close (< 10 mm) to the dividing line[2].
- **No CIB**: the copy is confined to the lower half of the sheet.

In addition, CA, independent of proximity to the model, was rated on a three-point scale, scoring zero points if unrecognisable (severe CA), one point if partially recognisable (moderate CA), and two points if accurate (no CA) (see Figure 3.1, top row, for examples), with the mean copy quality calculated across the figures. This scoring procedure differed from the original Figure Copying task of the MODA, in which each picture was rated as: recognisable (one point), partially recognizable (0.5 point), or not recognisable and/or touching or overlapping the model (zero), and the scores were summed across the three figures.

[2] The precise definition of near-type CIB is, to some degree, arbitrary. In previous literature (Gainotti, 1972; see also Chapter 2) it has been defined as "the tendency to make copies very near to the model". The present operational definition of the near-type CIB as within 10 mm of the dividing line, provided a more objective criterion.

Figure 3.1. Top row: left-to right, examples of severe and moderate CA, and accurate copying. Bottom row, left-to-right, examples of overlap-CIB, near-CIB and no CIB.



The scoring system attempted to evaluate CIB independently from other aspects of copy quality, but these scores nonetheless derived from the same test items, and might therefore be confounded one with another. To assess the seriousness of this problem, CIB classification (overlap-CIB, near-CIB, no CIB) was recoded as a dichotomous variable coding CIB presence/absence, and the strength of relation with the Figure Copying score and other MODA cognitive subtests was evaluated. CIB presence correlated only modestly with the Figure Copying score (Spearman's *rho* = 0.23, p< 0.001), at a level well within the range of its correlations with other subtests (from *rho* = .06, *p* = .064 for Prose Memory to .27, p< .001 for Digit Cancellation).

This modest relationship provides reassurance that copy quality and copy placement were meaningfully independent within the present scoring system. Notably, the original MODA Figure Copying score correlated much more highly with our revised Figure Copying score, *rho* = .66, $p < .001$, than with CIB presence, *rho* = .36, $p < .001$, indicating that the original scores were determined more by the quality than the placement of the copy.

RESULTS

Cross-sectional analysis of patients with AD

The assumption of normality was violated ($p < 0.001$) for all variables (see Appendix Chapter 3b), therefore the analyses were carried out using non parametric tests.

All the patients completed the square copying task. In the diamond and multipart figure copying task, respectively 16 (2%) and 36 (4%) drawings were missing. CA was found in 1421 drawings from a total of 2339 (60%: 49% moderate CA and 11% severe CA). Figure 3.2 (left panel) shows the percentages of drawings classified as severe CA, moderate CA, and normal performance. Friedman's tests on the frequency of CA (moderate and severe CA combined) confirmed a reliable effect of figure type for the CA scale, χ^2 (2) = 121.94, $p < .001$. Post hoc tests revealed a significant difference in the frequency of CA between square and diamond copying tasks, $z = -8.97$, $p < .001$, and between square and multipart figure copying task, $z = -9.55$, $p < .001$. The comparison between the frequency of CA in diamond and multipart figure copying task did not reach significance, $z = -1.45$, $p = .14$). A reliable effect of figure type for CA was found on the frequency of moderate, $\chi^2(2) = 36.87$, $p < .001$, and severe CA considered independently, χ^2 (2) = 96.35, $p < .001$. Post hoc tests found a significant difference between each copy drawing task comparison for both frequencies of moderate and severe CA[3].

[3] **Moderate CA:** square vs. diamond copying task, $z = -5.68$, $p < .001$; diamond vs. multipart figure copying task, $z = -1.97$, $p = .048$; square vs. multipart figure copying task, $z = -3.85$, $p < .001$.

Severe CA: square vs. diamond copying task, $z = -5.50$, $p < .001$; diamond vs. multipart figure copying task, $z = -5.43$, $p < .001$; square vs. multipart figure copying task, $z = -8.93$, $p < .001$.

CIB appeared in 588 drawings from a total of 2339 (25%: 15% near-type and 10% overlap-type). Figure 3.2 (right panel) shows the percentage of drawings classified as overlap-type CIB, near-type CIB, and no CIB for each of the three figures. Friedman's tests on the frequency of CIB (near- and overlap-type combined) confirmed a reliable effect of figure type for the CIB scale, $\chi^2(2) = 90.27$, $p < .001$. CIB became increasingly common as the complexity of the model increased, from square to diamond to multipart figure. Wilcoxon test showed a significant difference in the frequency of CIB between square and diamond copying tasks, $z = -2.59$, $p = .01$, square and multipart figure copying task, $z = -8.52$, $p < .001$, as well as between diamond and multipart figure copying task, $z = -6.59$, $p < .001$. A reliable effect of figure type for CIB was found on the frequency of near, $\chi^2(2) = 24.75$, $p < .001$, and overlap-type CIB, $\chi^2(2) = 45.34$, $p < .001$, considered independently. Post hoc tests showed a significant difference between each pairing of copy drawing tasks, except for between the square and diamond[4], for frequencies of both near and overlap-type CIB.

The percentage of drawings for each type of CA and CIB at each level of dementia severity is shown in Figure 3.3. A Kruskal-Wallis test on the frequency of CA (moderate and severe combined together) and CIB (near- and overlap-type combined) confirmed that as dementia severity increased both CA, $\chi^2(2) = 42.00$, $p < .001$, and CIB became increasingly common, $\chi^2 (2) = 36.09$, $p < .001$. Post hoc tests, with an uncorrected alpha level, confirmed a reliable difference in the frequency of CA and CIB between the different dementia severity groups of patients[5].

[4] **Near CIB:** square vs. diamond copying task, $z = -1.94$, $p = .052$; diamond vs. multipart figure copying task, $z = -3.13$, $p = .002$; square vs. multipart figure copying task, $z = -4.61$, $p < .001$.

Overlap CIB: square vs. diamond copying task, $z = -1.05$, $p = .292$; diamond vs. multipart figure copying task; $z = -4.97$, $p < .001$; square vs. multipart figure copying task, $z = -5.95$, $p < .001$.

[5] *Borderline vs. moderate dementia*: CA, $z = -3.93$, $p < 0.001$, and CIB, $z = -2.19$, $p = 0.028$; *moderate vs. severe dementia*: CA, $z = -4.78$, $p < 0.001$, and CIB, $z = -3.37$, $p < 0.001$; *borderline vs. severe dementia*: CA, $z = -6.05$, $p < 0.001$, and CIB, $z = -4.57$, $p < 0.001$.

Figure 3.2. CA. Left-to-right, examples of severe impairment, moderate impairment and normal performance on the CA scale. CIB: Left-to-right, examples of overlap-type CIB, near-type CIB and normal performance on the CIB scale.

In both plots, the black bar represents severe impairment, the grey bar moderate impairment and the white bar normal performance.

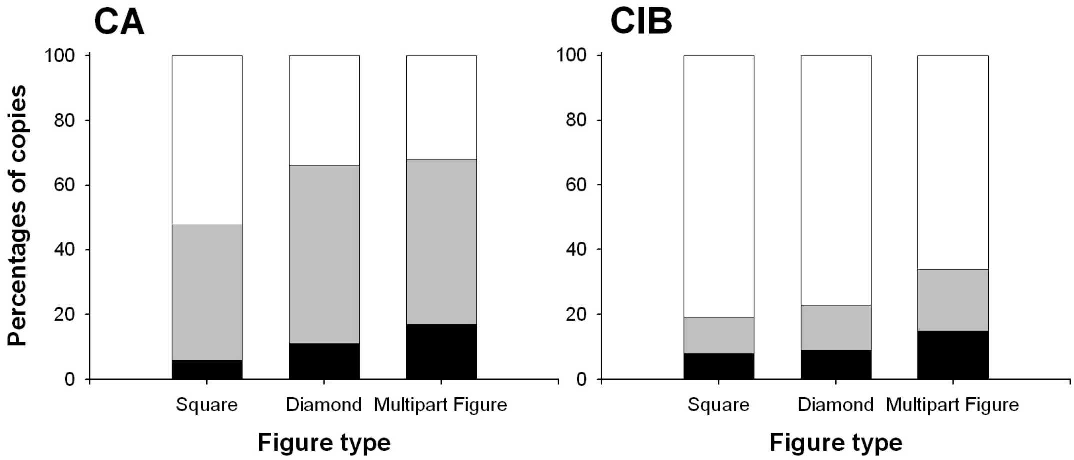
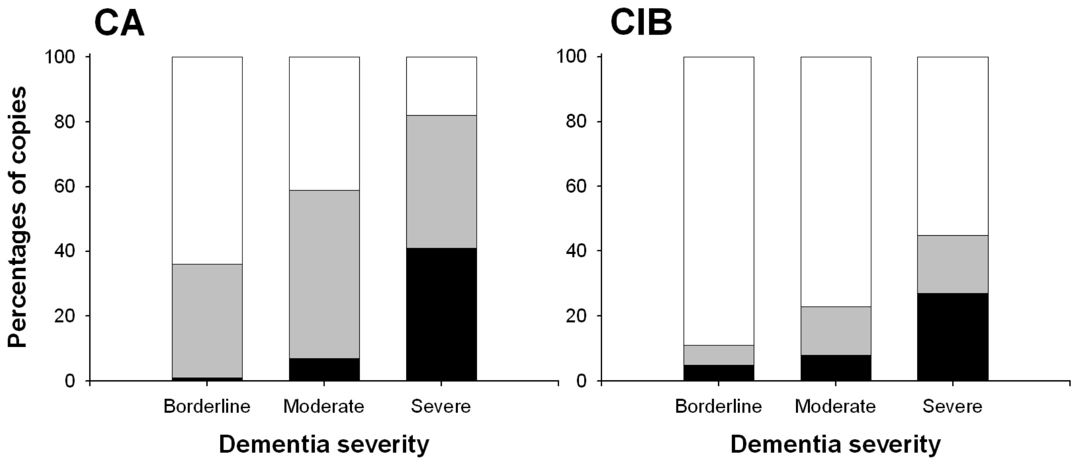


Figure 3.3 also shows the frequencies of moderate and severe CA and overlap- to near-type CIB. A Kruskal Wallis test found a reliable effect of dementia severity for both moderate, χ^2 (2) = 21.52, $p < .001$, and severe, χ^2 (2) = 173.21, $p < .001$, CA. Post hoc tests confirmed that the frequency of both moderate and severe CA was higher in groups of patients with more severe AD[6]. The only comparison which did not reach significance was for the frequency of moderate CA between borderline and severe dementia groups, z = -.52, p = .602. In relation to CIB, overlap CIB significantly increased with dementia severity, χ^2 (2) = 53.17, $p < .001$. Mann-Whitney test confirmed a significant difference in overlap-type CIB frequency between moderate and severe dementia, z = -7.08, $p < .001$, and between borderline and severe dementia, z = -3.85, $p < .001$; while no significant difference was found in the comparison between borderline and moderate dementia, z = -.813, p = .41. This trend of increase in frequency as the dementia severity also appeared for near-type CIB, though it did not reach significance, χ^2 (2) = 5.7, p = .057.

[6] *Borderline vs. Moderate dementia*: moderate CA, z = -2.92, p = 0.003, and severe CA, z = -2.41, p = 0.016; *Moderate vs. Severe dementia*: moderate CA, z= -3.85, p < 0.001, and severe CA, z = -12.55, p < 0.001; *Borderline vs. Severe dementia*: severe CA, z = -6.97, p < 0.001.

Figure 3.3. CA. Percentages of drawings classified at each level of the CA and CIB scales for the three figures. CIB: Percentages of patients classified at each level of the CA and CIB scales by dementia severity.

In both plots, the black bar represents severe impairment, the grey bar moderate impairment and the white bar normal performance.



In order to futher explore the relationship between CIB and CA, each patient was classified into a single CIB and CA category according to the presence or absence of these symptoms. CIB and CA did not always proceed in parallel; some dissociating performance could be gleaned from the data. In 312 cases, CIB was found in assoctiation with CA, but on 31 (4%) cases it was coupled with good copying accuracy. The reverse dissociation could also be observed, as 370 (46%) AD patients showing no CIB performed rather poorly on the CA task. Finally, 84 patients (11%) were able to accurately perform the copying task, without showing CIB.

A backward multinomial logistic regression analysis was conducted to explore the relationships between CIB and the various cognitive sub-tests of the MODA. The MODA subtests were all inter-correlated, rho > .12, p < .001 for all coefficients, presumably due to the common factor of disease progression, but multi-collinearity was not severe (no coefficient exceeded .53) (see also Appendix Chapter 3c). All ten predictors were thus entered into a backward multinomial logistic regression with CIB as the trinomial dependent variable (overlap CIB, near CIB, and no CIB). For this analysis, each patient was classified into a single CIB category according to their most severe manifestation of CIB. For instance, a patient showing no CIB, near and overlap CIB for respectively, the square, the diamond, and the multipart figure, was categorised as showing overlap-CIB. Using this scoring procedure, 164 patients (21%) were classified with overlap CIB and 179 (22.5%) with near- CIB

A test of the full model against a constant only model was statistically significant, Model χ^2 (4) = 98.09, p < .001, Cox & Snell R^2 = .116. The results are reported in Table 3.1 and the step summary is reported in the Appendix Chapter 3d. The distinction between near-type CIB and normal performance was best predicted by Digit Cancellation. The distinction between overlap-type CIB and near-type CIB was best predicted by Figure Copying and Digit Cancellation. Finally, the distinction between overlap-type CIB and normal performance was best predicted by Digit Cancellation and Figure Copying. Including age, years of education, and gender as additional predictors in this analysis produced the same outcomes.

The Figure Copying score and CIB classification derived from the same test items (see Material and Methods), therefore, there was a lingering concern that the strength of relation between these measures might be artefactually inflated. To address this concern, the first multinomial regression analysis was repeated excluding Figure Copying as a predictor. When this was done, the predictive role of Figure Copying was taken over by Street Completion, another measure of visuospatial ability. Thus, the distinction between overlap-CIB and near-CIB was predicted by Digit Cancellation and Street Completion, while the distinction between overlap-CIB and normal performance was predicted by Digit Cancellation and Street Completion. This provides further reassurance that the relationship between overlap-CIB and Figure Copying is due to the involvement of visuospatial factors, and not to any confound in the scoring system.

Table 3.1. Backward multinomial logistic regression.

		B	Wald	*p*	*Exp (B)*	95% confidence interval for *Exp(B)* Upper -Lower	
No CIB vs. Near CIB*	*Constant*	.153	.32	.571			
	Digit cancellation	.009	7.91	.005	1.010	1.003	1.016
	Figure copying	.106	.24	.619	1.112	.732	1.689
Near CIB vs. Overlap CIB*	*Constant*	-1.277	21.27	$p < .001$			
	Digit cancellation	.008	4.02	.045	1.008	1.000	1.016
	Figure copying	.825	10.35	.001	2.282	1.381	3.772
No CIB vs. Overlap CIB*	*Constant*	-1.124	20.63	$p < .001$			
	Digit cancellation	.018	24.68	$p < .001$	1.018	1.011	1.025
	Figure copying	.931	17.10	$p < .001$	2.537	1.632	3.94

* referred category

Longitudinal analysis

All the patients completed the square copying task in both testing sessions. In the first testing session, one (1%) drawing was missed for the diamond copying task and two (2%) drawings for the multipart figure copying task. In the second testing session, two (2%) drawings were missed for the diamond copying task and six (5%) drawings for the multipart figure copying task.

At the first assessment, CA appeared in 222 of 393 drawings (56%: 52% moderate CA, 4% severe CA), increasing to 245 of 388 drawings (63%: 51% moderate CA, 12% severe CA) at the second assessment. The relative frequency of severe CA increased between assessments, $z = -4.08$, $p < .001$, while no significant difference was found in the frequency of moderate CA between assessments, $z = -.67$, $p = .50$.

At the first assessment, CIB appeared in 76 drawings (19%: 15% near-type CIB, 4% overlap-type CIB), increasing to 125 drawings (32%: 17 % near-type CIB, 15% overlap-type CIB) at the second assessment. Notably, the relative frequency of overlap- to near-type CIB increased between assessments**.** While for overlap-type CIB, this increase was highly significant, $z = -3.95$, $p < .001$, for the near-type CIB it did not reach significance, $z = -.44$, $p = .656$.

The decline in performance in the overall MODA between first and second assessments was highly significant, $z = -9.61$, $p < .001$, as well as the decline in performance in each single subtest (see Appendix Chapter 3e).

A backward binomial logistic regression analysis was conducted to investigate the cognitive predictors of deterioration on the CIB scale between assessments. The changes in scores from the first to the second assessment, calculated as the score at first test minus the score at retest, for each of the MODA sub-tests were used as the ten predictor variables. CIB deterioration was coded as a dichotomous variable, with patients classified as deteriorating if, in the second assessment, they showed a more severe category of CIB, or more instances of CIB in the same category. One patient was excluded as he showed overlap-type CIB on all figures at the first assessment, so had no possibility for deterioration between assessments. The backward binary logistic regression had CIB deterioration as the binary dependent variable. The final regression model (Step 13) was statistically significant, χ^2 (2) = 14.00, $p < .001$, Cox & Snell $R^2 = .102$. CIB deterioration was predicted best by the deterioration in Digit Cancellation (see Table 3.2). Including age, years of education, and gender as additional predictors in this analysis produced the same outcomes.

Table 3.2. Backward binomial logistic regression.

		B	**Wald**	***p***	***Exp (B)***
Step 9	*Constant*	-.662	6.77	.009	.516
	Digit cancellation	.018	7.44	.006	1.019
	Verbal Fluency	.014	3.56	.058	1.014

Cross-sectional analysis of patients with FTD

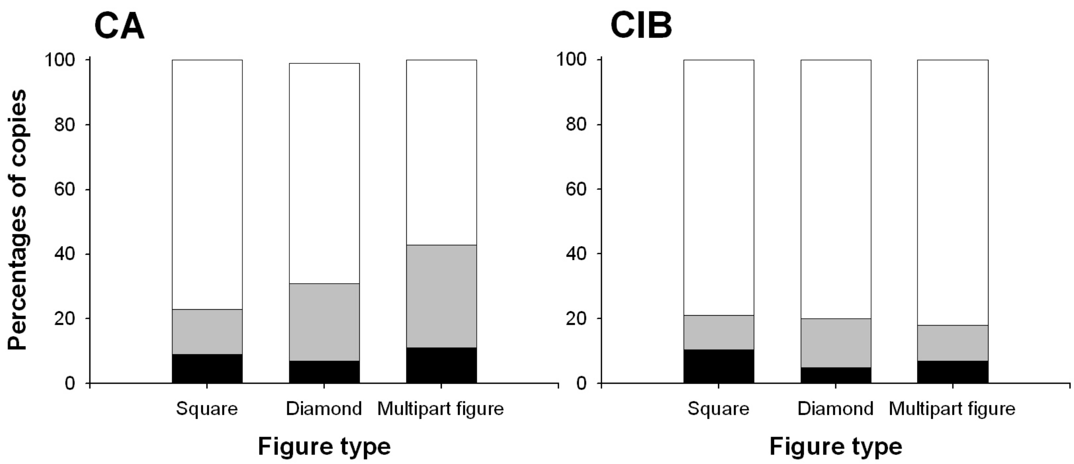
CA was found in 53 out of a total of 164[7] drawings (32%: 23% moderate CA and 9% severe CA). The percentages of drawings classified as severe CA, moderate CA, and normal performance are shown in Figure 3.4. Friedman tests on the frequency of CA (moderate and severe CA combined) confirmed a reliable effect of figure type for the CA scale, χ^2 (2) = 10.8, $p = .005$. Post hoc tests revealed that the only significant comparison for the frequency of CA was between square and multipart figure copying tasks, $z = -3.20$, $p = .001$. Wilcoxon's test did not find a significant difference between square and diamond copying tasks, $z = -1.73$, $p = .08$, or diamond and multipart figure, $z = -1.60$, $p = .109$. A Friedman test on the frequency of moderate and severe CA considered independently found a non reliable

[7] The total number of graphic copying tasks for 56 patients is 168. However two copying drawings were missed for the diamond and two for the multipart figure tasks. Therefore the overall total of drawings was 164.

effect of figure type for the frequency of severe CA, χ^2 (2) = 2.00, *p* = .36, and a trend toward significance for the frequency of moderate CA, χ^2 (2) = 5.54, *p* = .062.

Figure 3.4. CA: Left-to-right, examples of severe impairment, moderate impairment and normal performance on the CA scale. CIB: Left-to-right, examples of overlap-type CIB, near-type CIB and normal performance on the CIB scale.

In both plots, the black bar represents severe impairment, the grey bar moderate impairment and the white bar normal performance.

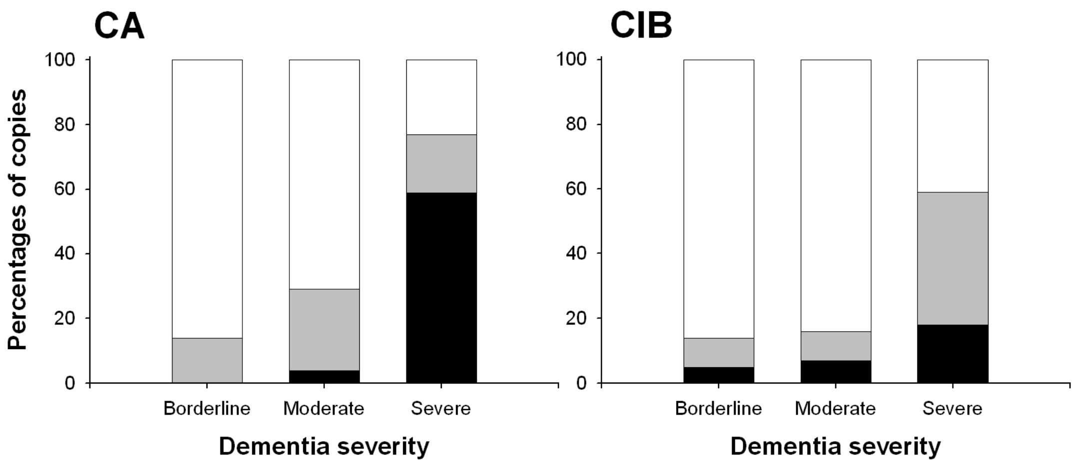


CIB appeared in 38 drawings from a total of 164 (20%: 12% near-type and 8% overlap-type). The percentage of drawings classified as overlap-type CIB, near-type CIB, and no CIB for each of the three figures are reported in Figure 3.4. In this group of patients, the frequency of CIB did not increase as the complexity of the model increased, from square to diamond to multipart figure. This lack of complexity effect concerned not only the overall frequency of CIB (near- and overlap-type combined), χ^2 (2) = .429, *p* = .80, but also the relative frequencies of near, χ^2 (2)= .571, p = .71, and overlap-type CIB, χ^2(2) = 1.75, *p* = .41.

The percentage of drawings for each type of CA and CIB at each level of dementia severity is shown in Figure 3.5. Kruskal-Wallis test on the frequency of CA (moderate and severe combined together) and CIB (near- and overlap-type combined) found significant difference between borderline, moderate, and severe dementia in CA, $\chi^2(2) = 6.20$, $p = .045$, but not in CIB, $\chi^2(2) = 3.77$, $p = .151$. The relative frequency of moderate and severe CA and overlap- to near-type CIB are shown in Figure 3.5. A Kruskal-Wallis test found no significant increase in frequency of moderate, $\chi^2(2) = 1.11$, $p = .57$, while severe CA increased significantly with dementia severity, χ^2 (2) = .26.06, $p < 0.001$. Finally, no significant increase in frequency of near, $\chi^2(2) = 2.44$, $p = .29$, or overlap CIB, $\chi^2(2) = 1.21$, $p = .54$, was found.

Figure 3.5. CA. Percentages of drawings classified at each level of the CA and CIB scales for the three figures. CIB: Percentages of patients classified at each level of the CA and CIB scales by dementia severity.

In both plots, the black bar represents severe impairment, the grey bar moderate impairment and the white bar normal performance.



As for the AD group, each patient with FTD was classified into a single CIB and CA category and some dissociating performance could be gleaned from the data. In 13 (23.2%) cases, CIB was found in assoctiation with CA, but on 6 (11%) cases it was coupled with good copying accuracy. The reverse dissociation could also be observed, as 16 (29%) FTD patients showing no CIB performed rather poorly on the CA task. Finally, 21 patients (37.5%) were able to accurately perform the copying task, without showing CIB.

Frequencies of CA and CIB in AD and FTD

As previously mentioned in the Material and Methods section, patients with AD and FTD were not matched for demographic characteristics or severity of dementia. However, the frequency of CA and CIB in AD and FTD were compared at each level of dementia severity. In order to perform a chi square test, each patient was classified into binomial CA (presence or absence of CA) and CIB (presence or absence of CIB) scales according to their most severe manifestation of CA and CIB in any of the three pictures (the same procedure was used in the cross-sectional regression analysis for AD group).

CA was significantly more common amongst patients with AD than with FTD in moderate, $\chi^2(1) = 32.16$, $p < .001$, and severe, $\chi^2(1) = 7.22$, p = .01, dementia. On the contrary, a similar frequency of CA was found between AD and FTD at a borderline level of dementia, $\chi^2(1) = 3.47$, p = .10. By contrast, the frequency of CIB did not differ between the two patient groups in either borderline, $\chi^2(1) = 1.03$, $p = .50$, moderate, $\chi^2(1) = 2.37$, p = .20, and severe dementia $\chi^2(1) = .12$, p = .80.

DISCUSSION

This retrospective study exploring CIB in patients with AD constitutes the largest survey of this symptom yet reported, and incorporates the first longitudinal analysis. The availability of data from additional cognitive tests allowed for an exploration of cognitive factors associated with CIB in AD. Moreover, the cross-sectional data of FTD patients allowed the first systematic assessment of this symptom in this cohort. This set of data thus allowed for the replication of prior observations in a large sample of patients with AD, for several important novel analyses exploring the cognitive predictors of CIB in AD, and for the evaluation of CIB features in FTD and AD.

First, the cross-sectional and longitudinal study of AD patients will be considered. Second, the cross-sectional study with FTD will be examined, comparing the appearance of CIB in patients with FTD and AD. Finally, some general methodological issues will be discussed.

Cross sectional and longitudinal study with AD patients

CIB became more frequent with increasing severity of AD (De Ajuriaguerra et al., 1960; Gainotti, 1972; Ober et al., 1991), and the frequency of overlap-CIB increased relative to near-CIB (Gainotti, 1972). This evidence supports the attraction hypothesis which considers CIB as a primitive default behaviour which reappears in the course of dementia. Moreover, this study confirmed the increase of CA frequencies with increasing dementia severity, showing a parallel pattern to CIB (De Ajuriaguerra et al., 1960). These patterns were shown in the cross-sectional analysis with AD and also, critically, in the longitudinal sample. A reliable effect of figure complexity upon CIB and CA was also confirmed, with the symptom becoming more frequent, and more frequently manifesting as the overlap-type, as the figure increased in complexity (Grossi et al., 1978; Mayer Gross, 1935; Muncie, 1938).

CIB has traditionally been considered a form of CA (Critchley, 1953; Grossi and Trojano, 1999; Mayer Gross, 1935), implying a visuo-spatial problem at its root. In the present study, CIB and other aspects of CA were assessed independently. The regression analyses exploring the cognitive predictors of CIB strongly support the view that visuo-spatial impairments are not the exclusive cause of CIB. The multinomial regression analysis suggested that different combinations of factors may underlie respectively, near-type and overlap-type CIB. The emergence of near-type CIB from normal performance was predicted by impairment on attentional tasks, with the step from near-type to overlap-type associated with visuo-spatial impairment and attentional tasks. Consistent with this, overlap-type CIB was distinguished from normal performance by a combination of attentional and visuo-spatial problems. The regression analysis of the longitudinal sample produced consistent findings, in that deterioration on the CIB scale was associated with deteriorated attentional performance. Taken together, these regression analyses support an attraction hypothesis of CIB (De Ajuriaguerra et al., 1960; Gainotti, 1972; Lee et al, 2004), according to which, the symptom reflects a primitive attraction of the hand toward the focus of attention, released by a depletion of attentional resources (Conson et al, 2009; Kwon et al, 2002; McIntosh et al, 2008). However, visuo-constructional problems also play an important role, especially in the expression of the more dramatic overlap-type CIB. The near- and overlap-types of CIB may thus, not lie on a simple continuum of severity, as previously assumed, but may reflect differential involvement of attentional and visuo-spatial factors.

In other words, the present study suggests that a depletion of attention resources is the primary factor eliciting the appearance of CIB and that the difficulty of the task might play a role in increasing the attentional demand and consequent tendency to migrate toward the focus of attention. Impairment in visuo-constructional abilities is likely to be observed together with attentional problems when patients perform the copy directly on the top of the model (overlap-type CIB). Thus, visuo-constructional deficits and general cognitive decline may induce severe CIB by increasing the subjective difficulty of copying tasks.

To date, the present study is the largest survey of CIB ever conducted in AD, or any other population. However, whilst the sample size and the longitudinal subgroup are obvious strengths of the data, the retrospective survey method also imposes important limitations. The MODA test battery was created for clinical purposes, not to test between competing hypotheses of CIB, so the mappings between specific subtests and the cognitive domains of interest (visuospatial, working memory, and attentional functions) are somewhat rough and serendipitous rather than designed. Moreover, clinical tests such as the MODA subtests are typically sensitive within a limited range of ability, and often prone to compression at one or both ends of the scale. Thus, ceiling and floor effects were apparent in the distributions of many of the MODA subtest scores. This was especially serious for the prose memory subtest, in which 75% of patients scored zero at the first assessment. This floor effect is unsurprising, given that the diagnosis of AD requires memory impairment, but it implies that the present analysis will have been very limited in its ability to differentiate between CIB subtypes on the basis of variations in memory capacity. In addition, although digit cancellation was characterised as a relatively specific measure of attention (Della Sala et al., 1992), it nonetheless incorporates visual scanning and recognition components, so a contribution of visuospatial factors to near-type CIB cannot be definitely excluded. For instance, this kind of task requires the ability to attend stimuli, ignoring irrelevant information, and is therefore considered to be a measure of selective attention (Della Sala et al., 1992).

However, working memory and visuospatial abilities are also required to correctly perform the task and deficits in these cognitive functions can also be responsible for poor task performance. For example, it has been proposed that additional working memory deficits are responsible for the tendency for oversearching in the rightward location observed in cancellation tasks by patients with neglect (Husain, Mannan, Hodgson, Wojciulik, Driver, & Kennard, 2001). This hypothesis suggests that patients with neglect forget that have already searched in the right half of the paper and continue to search at that location. These limitations indicate that the present findings must be considered suggestive, rather than definitive, pointing the way toward future, more specifically targeted investigations of the cognitive determinants of CIB.

The suggestion of the present survey is that attentional deficits are key determinants of CIB in patients with AD, supporting the view that this symptom reflects a default behaviour characterized by a manual bias toward the focus of attention. Although this symptom is not central to the clinical profile of AD, it might nonetheless have important functional implications. CIB could manifest in daily life as a tendency to veer toward objects of attention, raising the likelihood, for instance, of collision with salient visual cues (road signs or even pedestrians) during driving. If this tendency is secondary to attentional depletion, then it may also be observed in other drivers with reduced attentional capacity, regardless of their diagnosis. A further implication of the present study, however, is that the most florid, overlap form of CIB, in which the copy is performed directly on the model, does not simply represent an extreme form of this veering behaviour. Rather, overlap-CIB may typically require visuospatial impairment. If this is correct, then near and overlap manifestations do not lie on a simple continuum, as has previously been assumed, but also reflect differential involvement of attentional and visuospatial factors.

Cross sectional analyses with FTD patients in relation to AD cohort

This study represents the first assessment of CIB in FTD and demonstrates the presence of this phenomenon in this cohort. FTD patients showed clear increases in the frequency of CA with visuospatial complexity. On the contrary, CIB frequency in FTD was unaffected by the complexity of the task, thereby showing a surprising independence from visuospatial demands. CA and CIB showed higher frequencies in severe FTD dementia, although these patterns were not statistically significant. At each level of severity, CA was significantly more common amongst patients with AD than with FTD. This result is consistent with previous evidence of relatively preserved constructional skills in FTD (Edwards-Lee et al., 1997; Miller et al., 1998). In contrast, the frequency of CIB did not differ between the two patient groups at any level of dementia severity. The divergent profiles of CA and CIB suggest that there is no simple relationship between these symptoms, and raises the possibility that CIB may be differentially determined by different cognitive factors in the two groups.

Taken together these findings suggest that CIB is as common in FTD as in AD, but also that the phenomenon might have different causes in these two conditions. Patients with AD show more frequent CA and a significant effect of visuospatial complexity on CIB, implying an important role for visuospatial deficits.This hypothesis has found further support in regression analysis, which showed the combination of attentional and visuo-spatial problems as the best predictor of Overlap CIB in AD. In patients with FTD, by contrast, CA is relatively rare, and CIB is independent of figure complexity. It has been suggested, for patients with corticobasal degeneration, that CIB may reflect a primitive, automatic attraction toward salient visual stimuli, rather than a true visuospatial impairment (Kwon et al., 2002; Conson et al., 2009). This hypothesis may also account for the CIB exhibited by patients with FTD. For instance, the nature of CIB might be more primitive, consisting of a manual attraction towards any relevant visual stimuli, released by reduced executive control. In patients with AD, the apperence of CIB might, instead be related to a combination of visuospatial and attentional deficits. This hypotheis is speculative and future studies should be addressed to explore this issue. However, some initial evidence of this different nature of CIB in these two populations has been shown in the present study, since the complexity of the copying task had an effect in the apperence of CIB in AD, but not in FTD, but also from previous literature. For instance, CA and visuospatial deficits have been shown to be a symptom of AD, but less prominent in FTD (Rascovsky et al., 2002). Morever, a recent study with patients with AD (Serra, Fadda, Perri, Caltagirone, & Carlesimo, 2009) showed that poor performance in visuospatial task is the key determinant in distinguishing patients with overlap-type CIB and those without CIB. The results of this study supported the idea of the important role of the visuospatial deficits in the appearence of CIB in patients with AD.

Methodological issues in CIB scoring procedure

In the present study, a new methodological approach in CIB categorization was applied: CIB was rated by copy positioning, independently from CA. This approach aimed to bypass the theoretical assumption of CIB as a symptom of CA and to allow the consideration of the two as separate signs (see also Chapter 2). This new methodological approach created some controversial issues in practical application and in particular, for overlap CIB. This type of CIB incorporates the copy drawings touching the division line or performed above the division line (i.e. in the model's space). When the copy was performed in the model's space, three kinds of behaviours were observed: 1) the copy remained detached from the model; 2) the copy partially overlapped the model, and 3) the copy wholly overlapped the model. While in the first two cases, the assessment of CA was possible without any influence from the copy positioning, the third behaviour appeared in conjunction with severe CA (scribble) (4%), and also with the tendency to trace the lines of the model (2%). In cases in which this tracing strategy was successful, so that the patients accurately traced all the elements of the model, the performance would be evaluated as severe CIB but not CA. However, of course, it is unclear whether CA is really absent in such cases, because it may have been successfully masked by the tracing strategy. The present methodological approach might be valid from a theoretical point of view, but must be tested in a future study with specific tasks for the assessment of CA independently from CIB (i.e. drawing on command). In the present study this assessment was not possible because of the retrospective nature of the data set.

Another methodological aspect to be taken into account is the classification of CIB. The precise categories created for the CIB rating scale were, to some degree, arbitrary. As stated in the methods, the operational definition of both CIB types aimed to provide a more objective criterion for the assessment of this specific behaviour, previously described in the literature as the tendency to perform a graphic copying very near to the model (near- type CIB) or directly on the top of the model (overlap-type CIB). In order to obtain control data for the present CIB scoring procedure, protocols of 85 healthy participants (median 66 years of age; range 41-85) stored in San Paolo archive were also re-collected and the Figure copying task of the MODA was rescored using the present scale. In this cohort, 15 (18%) adults were classified with near-type CIB and only one subject was classified with overlap-type CIB. The presence of CIB in this group of adults might be explained in a different ways. This group of adults underwent neuropsychological assessment because they were noticing cognitive problems in their daily life which did not find confirmation in the testing session. First, it cannot be certain that these subjects did not develop dementia at a later time. Another explanation of the appearance of CIB in elderly participants might be that CIB, the near-type in particular, may be a phenomenon not simply confined to pathology but visible in normal aging too. A previous study (Kwak, 2004) obtained similar results, showing the appearance of the near-type of CIB in 10% of elderly adults, while this symptom was not found in young adults. The author suggested that this form of CIB could indicate a phenomenon related to aging process, in that the near-type of CIB might be related to the physiological decline of attention and executive functions. This hypothesis could find support in the present regression analysis, which showed that the attention subtest was the unique predictor of the near-type CIB in AD, and from aging studies, which underlined the involvement of the frontal lobe (Fuster, 1989) and the decline of executive functions in normal aging (Albert & Kaplan, 1980; Shimamura, 1990). However, this hypothesis is speculative and future studies should be devoted in exploring the appearance and the cognitive nature of the near CIB in elderly subjects.

CONCLUSIONS

In summary, this study explored the appearance and the cognitive basis of CIB in AD. The present findings show support for the attraction hypothesis of CIB, which suggests that the primary factor responsible for the emergence of CIB is a deficit of attention which leaves the patient at the mercy of a primitive automatic attraction toward the model. However, additional visuo-constructional problems may be necessary to elicit overlap-type CIB, which, in the most severe end-state, reduces the patient to scrawling on the model. The near- and overlap-types of CIB may thus not lie on a simple continuum of severity, as previously assumed, but also reflect differential involvement of attentional and visuospatial factors. However, as previously discussed, the retrospective nature of this study did not allow a direct assessment of attention and the attentional task used in the present study presented visuospatial and working memory components. Therefore, the present results must be considered as indicative but not definitive, and the possible involvement of visuospatial and working memory deficits in the appearence of CIB should be further explored.

Moreover, the assessment of CIB in a smaller cohort of patients with FTD showed that the phenomenon can be observed in this form of dementia too, in a similar frequency as in AD. The result of the present study further suggests that in patients with FTD, CIB is a primitive, automatic attraction toward salient visual stimuli.

Although the present study shows evidence in support of the attraction hypothesis of CIB, its retrospective nature did not allow a direct test between the two competing hypotheses of CIB. Therefore, the following two chapters will be devoted to further investigating the cognitive nature of CIB and to testing (experimentally) between the compensation and attraction hypothesis of CIB in a single case (Chapter 4) and in a small cohort of patients with AD (Chapter 5).

CHAPTER 4
A single case study of Closing-in Behaviour in Alzheimer's disease.

INTRODUCTION

In the previous chapter, the frequency and characteristics of CIB were examined in 797 patients with Alzheimer's disease, 132 of who were followed up longitudinally. The frequency of CIB increased with the complexity of the graphic copying task and with the severity of AD. Regression analyses showed that attentional deficits are critical factors for the appearance of CIB, but that visuospatial impairments also play an important role in the emergence of severe forms of CIB.

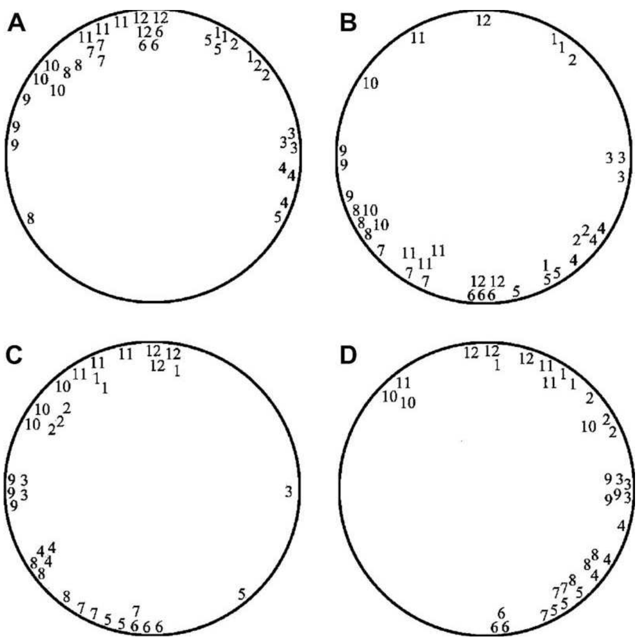
In the present study, these results were investigated further in a patient with AD, who showed CIB in graphic and gestural copying tasks. In particular, the two main contemporary candidate hypotheses proposed to explain the nature of the phenomenon have been tested experimentally in this patient. As described in Chapter 2, the 'compensation' hypothesis, probably traceable to Muncie (1938), proposes that CIB reflects a strategic adaptation to balance an underlying cognitive impairment. On this view, CIB emerges as an attempt to compensate for an impaired ability to represent the model (Lee et al., 2004) and/or to retain that representation across the intervals required to make a spatially-removed copy (Kwon et al., 2002; Lee et al., 2004). By decreasing the distance between the copy and the model, the burden on visuospatial analysis and/or working memory can be reduced. In the extreme case, this strategy would convert the copying task into a direct tracing task, relieving the patient of the need to set up or store an abstract representation of the model at all.

An alternative hypothesis is that CIB represents a primitive, default behaviour in which the acting hand is drawn toward the focus of visual attention (the model) (De Ajuriaguerra et al., 1960; Gainotti, 1972; Kwon et al., 2002). In its bare form, the 'attraction' hypothesis is under-specified, since it is not clear what precipitates the release of this default behaviour. Kwon et al. (2002) have suggested that the precipitating condition is frontal dysfunction, implying a deficiency of executive and/or attentional resources (see also Conson et al., 2009; Gainotti, 1972; Lepore et al., 2005). The details of this account will be considered in later discussion, but the basic proposal is crucially distinct from that of the compensation hypothesis. According to the attraction hypothesis, CIB is not strategic, and would not be expected to aid copying performance; it is merely a default state released by a breakdown of normal control processes.

As described in Chpater 2, there have been three recent attempts to test the above hypotheses. Kwon et al. (2002) studied a patient with corticobasal degeneration, who exhibited CIB in gesture imitation. The experiment was designed to test the compensation hypothesis, with the prediction that CIB should be more pronounced when gesture complexity was increased, or when a more complex spatial transformation was demanded by having the patient sit facing, rather than alongside the examiner. However, no reliable influence of either manipulation was observed, which led the authors to reject the compensation hypothesis in favour of an attraction account. Subsequently, Lee et al. (2004) tested a group of 13 patients with AD on a graphic copying task, presenting horizontally extensive 'Luria' figures, and estimating the slope of the patients' copies as an index of CIB. In this experiment, both figure complexity and the distance of the designated starting position from the model were manipulated. The prediction drawn from the compensation hypothesis was that complexity should increase CIB by adding to the visuospatial and memory load, and that compensation would be more pronounced for starting positions further from the model. The data robustly confirmed the expected effect of complexity, but no reliable influence of starting position was obtained. Nonetheless, the authors concluded in favour of the view that CIB arises as a strategic compensation for visuospatial or working memory dysfunction. Finally, Conson et al. (2009) described the case of a patient with frontal-subcortical dysfunction, who showed CIB without severe constructional disabilities. Moreover, the patient showed a specific impairment in monitoring and inhibiting automatic responses. The nature of CIB in this patient was assessed in three experiments. First, the authors manipulated the complexity of the graphic copying task and observed an effect of complexity on the accuracy of the copy but not on CIB. This result was interpreted as supportive of the primitive default nature of CIB. In the second experiment the patient was asked to draw in two different conditions: under the visual guidance of the model (graphic copying) and under verbal instruction (drawing on command). The accuracy of the performance markedly improved when the model was not presented, suggesting that CIB might be independent from constructional disability and might even interfere with the drawing performance in standard copying tasks. In the third experiment, the patient was asked to reproduce different spatial locations of a bar positioned at the edges of a circular shape. The position of the bar within the circular frame was varied as assuming the different positions that the numbers have in the clock. The patient performance was influenced by the position of the model, showing a spatial transposition of the bar toward the position of the model. This spatial transposition was constant and respected the spatial relationships that the numbers have within the clock (e.g when the model with a bar located at 6, was placed on the top of the circular frame, the patient reproduced at 12). The authors interpreted this behaviour in this patient as evidence of CIB within preserved visuospatial processing (see Figure 4.1).

Figure 4.1. Performance of the patient described by Conson et al. (2009) when the model was presented on the top (A), on the bottom (B), on the left (C) and on the right (D).

The numbers indicate the position of the bar in the original model and their locations represent the patient's copying performance.



How can the apparently conflicting findings of these studies be reconciled? On the one hand, Kwon et al. (2002) and Conson et al. (2009) did not find a significant influence of the complexity of the task in the apperence of CIB, and interpreted these failure as a supportive evidence of the primitive nature of CIB, but this is contrary to the weight of evidence, which indicates that figure complexity is a cardinal determinant of CIB (e.g. Lee et al., 2004; Mayer Gross, 1935; Muncie, 1938). It would thus seem unwise to base any firm or general conclusions on this isolated null finding, especially given that two single cases of possibly atypical CIB (associated with corticobasal degeneration) were studied. On the other hand, Lee et al.'s (2004) support for the compensation hypothesis was based entirely upon the effect of figure complexity. As stated in Chapter 2, it can be argued that this does not constitute a critical test between the compensation and the attraction accounts. The attraction account proposes that the acting hand is drawn to the focus of visual attention, so any manipulation that increases focal attention to the model might be expected to exaggerate this effect. It could thus be argued that the observed effects of figure complexity are fully compatible with an attraction account or the compensation hypothesis, and thus provide equivocal support for either. A more decisive empirical test is required.

The most obvious factor distinguishing the compensation and attraction hypotheses is that in the former, CIB is a functionally adaptive strategy to aid copying performance, whilst in the latter it is non-functional, arising only because the patient fails to inhibit the default behaviour. The compensation hypothesis thus predicts that CIB should be specific to situations, such as copying, in which manual performance could benefit from information available elsewhere. By contrast, the attraction hypothesis predicts that manual performance in patients with CIB should migrate toward any sufficiently attention-demanding visual stimulus, regardless of its relevance to the manual task.

In the present study, these predictions were tested in a patient with AD and CIB. A clear effect of figure complexity on CIB was reported in both graphic and gestural copying tasks. Critically, the results show that manual performance is strongly attracted toward the focus of attention defined by an *unrelated* visual discrimination. These data demonstrate that CIB is not specific to copying tasks, and provide firm evidence for the attraction hypothesis rather than the compensation account, at least for this patient. In discussing these findings, the cognitive factors which might underlie the release of a primitive manual attraction toward the focus of visual attention will be considered.

MATERIALS AND METHODS

Case report

Patient WS was a 62 year old woman who had been diagnosed with AD three years prior to this study[8]. WS was aware of her diagnosis and of her cognitive difficulties, showing frustration, and sometimes distress, when unable to complete tests to her satisfaction. However, she was co-operative and motivated throughout the assessments, which were conducted over a ten-month period.

General cognitive status

At the first assessment, WS's dementia was classified as 'moderate', according to the Washington University Clinical Dementia Rating (Morris, 1993). She scored 63/100 in the Addenbrooke's Cognitive Examination (ACE: Mathuranath et al., 2000), and achieved 21/30 in the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975). WS showed CA and CIB in the graphic copying parts of the ACE, producing no recognisable reproductions, but scrawling near to or on top of the models. At the final assessment, the ACE was re-administered: WS's total score (54) and MMSE (17) sub-score were reduced relative to the first assessment, suggesting moderate progression of dementia over the course of the present studies.

The profile of sub-scores on the ACE, averaged across the two assessments, suggested typical memory problems (19/35), mild impairments of orientation (5.5/10) and attention (5/8), and poor verbal fluency (4.5/14) in the context of relatively preserved language (24/28). A pronounced impairment of visuospatial abilities (0.5/5) was observed on constructional and writing tasks; constructional abilities were explored more extensively using further copying tasks (see Assessment of CA, below).

[8] This patient was a volunteer recruited from an Alzheimer's disease association in Glasgow. Therefore, information regaring her clinical record was not available for the present study.

Further neuropsychological assessments

WS's husband reported a slight tendency for her to neglect the left side, which was confirmed by the administration of Albert's (1973) line cancellation test. WS cancelled only 23 of the 36 lines on this test, with more than twice as many omissions on the left side of the sheet than on the right (10 vs. 3); she also tended to perseverate, cancelling eight of the lines more than once. WS showed no sign of optic ataxia, being able to reach accurately, with either hand, to targets in both visual hemifields.

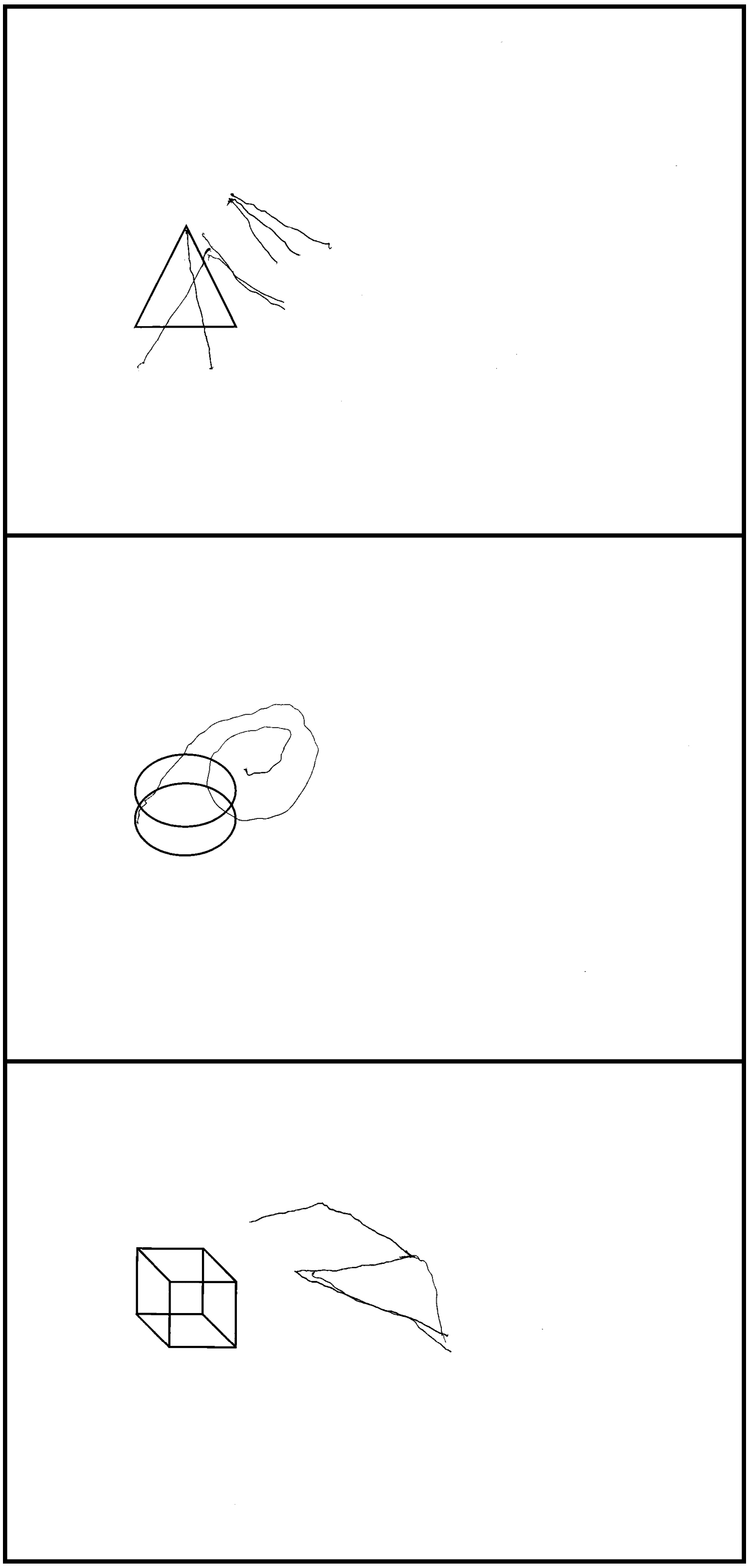
The cognitive functions assessment of primary relevance to the compensation and attraction hypotheses of CIB was attempted. Assessment included the Digit Span Test of the WAIS-R (Wechsler, 1981) for verbal memory, and the Corsi blocks task (Corsi, 1972) and Visual Patterns Test (Della Sala, Gray, Baddeley, &Wilson, 1997) respectively for spatial and visual working memory. WS's digit spans were 6 (forward) and 3 (backward), giving an overall age-scaled score of 6 (within 2 *SD* of the normal mean). Her Corsi block span of 2 was well below the normal range (z = -2.92). Unfortunately, she had difficulty following the instructions for the Visual Patterns Test, becoming confused and distressed, and this test was abandoned. Similar problems bedevilled the attempts to assess attentional functions using the, relatively complex, map search, visual elevator and elevator counting subtests of the Test of Everyday Attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994); no meaningful scores could be derived from these.

These assessments lend some circumstantial support to the idea that CIB arises in compensation for impaired visuospatial functions and/or working memory. WS's low Corsi span is indicative of poor visuospatial working memory, which may be related to the poor visuospatial abilities indicated by her ACE profile. However, caution should be exercised here, since the neuropsychological tests employed are relatively non-specific (e.g. the Corsi blocks task has significant executive components: Richardson, 2007), and since WS's inability to perform many of the presented tests implies pervasive cognitive difficulties. The association of visuospatial impairments and CIB in this patient does not establish any causal connection, although it may inform the interpretation of the present experimental results.

Assessment of CA

To provide a fuller assessment of graphic copying performance, WS was asked to copy nine pictures, three at each of three levels of complexity: simple, medium and complex. The simple stimuli were geometrical figures (square, circle, and triangle); the medium-complexity stimuli were overlapped pairs of geometrical figures (overlapped squares, ellipses, and triangles); the complex stimuli were two-dimensional representations of three-dimensional figures (cube, cylinder, and pyramid). Each stimulus was presented within the left half of an A4 sheet, in landscape orientation. WS did not produce a single recognisable reproduction in these trials. Moreover, CIB was observed consistently, with six from nine of the attempted reproductions touching or overlapping the model in some part (see Figure 4.2 for examples).

Figure 4.2. Representative examples of WS's attempted reproductions in the graphic copying screening task, showing pronounced CA and CIB.



Assessment of apraxia

WS's performance in copying gestures was assessed using a range of unimanual gestures. Six transitive gestures (writing with a pen, cutting with scissors, unlocking a door with a key, stitching with a needle, slipping a ring on, using a lighter) and six intransitive gestures (peace sign, beckoning with finger, stop sign, giving a punch, waving goodbye, indicating that something is good) were selected from Bartolo, Cubelli, and Della Sala (2008), and seven meaningless gestures (palm down, palm up, palm lateral, fist down, fist up, fist lateral, index, and little finger up) were selected from Kwon et al. (2002). Each gesture was first attempted in response to a verbal instruction, and then in imitation of the examiner, with gesture type blocked (as recommended by Cubelli, Bartolo, Nichelli, & Della Sala, 2006). The transitive gestures were then re-performed as a pantomime (i.e., without the object present): first to verbal instruction, next in imitation of the examiner without the object being named, and finally in imitation of the examiner with the object name spoken. Throughout this assessment, the examiner faced WS across a small table, with a 64 × 46 cm sheet of paper placed between them, oriented horizontally. This sheet was divided in half lengthways by a thick black line. At the outset, and at regular intervals, it was emphasised to WS that she should perform her movements in her own workspace, on her side of the black line. Both the examiner and WS performed all gestures with the right hand.

For each gesture, the accuracy of reproduction was rated on a scale of 0-2, according to the following descriptors:

0: the gesture is different from the one required.

1: the gesture is similar to the one required.

2: the gesture is correct.

CIB was also rated on a scale of 0-2, using the tendency to respond toward the examiner's side of the workspace as the criterion:

0: the gesture is performed in the patient's own workspace.

1: the gesture is performed on top of the dividing line between workspaces.

2: the gesture is performed in the examiner's workspace.

The apraxia assessment data were not sufficiently extensive to support statistical analysis, but some qualitative trends can be sketched. First, in terms of gesture quality, WS performed relatively well for transitive gestures using real objects (mean score 1.84), but less well when imitating a pantomime with the object named (mean score 1.50), and more poorly again when imitating a pantomime without the name (mean score 1.17) or pantomiming to verbal instruction (mean score 1.17). Relative to transitive gestures using real objects, intransitive and meaningless gestures were performed poorly overall (mean scores 1.34 and 1.43 respectively).

Within a contemporary cognitive model of apraxia, this pattern could suggest a generalised impairment of the praxic system, selectively sparing object use at the level of the praxis output lexicon (Cubelli, Marchetti, Boscolo, & Della Sala, 2000). This relative sparing could be an epiphenomenon induced by the patient's general reduction of available cognitive resources: affordance-like effects produced by the additional tactile and kinaesthetic information could make the use of a real object easier than analysing complex meaningless configurations, or accessing the working memory system to process pantomimes (Bartolo, Cubelli, Della Sala, & Drei, 2003).

In terms of CIB, the patterns of performance were clear and unsurprising. CIB emerged only mildly when gestures were instructed verbally (mean score 1.50), but much more strongly across the various imitation conditions (mean score 0.66), in which there was a model to copy from, and to migrate toward.

EXPERIMENT 1: CIB IN GRAPHIC TASKS

Procedure

Preliminary graphic copying task

Patient WS was asked to copy two simple figures, presented on A3 paper in landscape orientation on a tabletop. The simpler figure was a straight black line; the more complex figure was a Luria's figure (after Luria, 1966) with 10 square units; each model was 340 mm long, centred on the long axis of the paper, and presented 41 mm from the top or bottom edge of the paper (see Figure 4.2, Results). Each sheet also had a black dot (6 mm diameter) centred vertically on the sheet, in horizontal alignment with the left end of the model[9]. The instruction was to place the pen on the starting point at the centre of the dot, and to copy the model from left to right. Two blocks of twelve trials were attempted, one before the experimental task (see below), and the other after it. In the first block, figure complexity was manipulated according to a repeating ABBA schedule, with the simple figure first, and figure position alternated between trials, beginning with the figure at the top. This trial order was reversed in the second block. Unfortunately, the first block of trials was curtailed, resulting in a reduced number of trials for this block (see Results section).

CIB on the drawing task was quantified by two alternative dependent variables. First, the average deviation of the drawn line from the centre of the page was estimated by averaging the vertical coordinates of the line at the horizontal co-ordinate of the start position and at successive rightward increments of 20 mm until the right hand edge of the paper was reached or the drawn line was no longer present. Deviations toward the model were signed positively and deviations away from the model were signed negatively, and this value was expressed as a percentage of the vertical distance between start position and model. Additionally, following the method of Lee et al. (2004), the vertical co-ordinates were regressed upon the horizontal co-ordinates for each trial, taking the slope of the best-fitting straight line as the dependent variable. Assuming that a linear relationship is obtained, the slope indicates the degree to which the drawn line veers away from the horizontal on a given trial, with veering toward the model producing a positive slope, and veering away from the model a negative slope. Extensive piloting of versions of this task indicated that normal adults show no tendency to deviate toward the model, although they may have a default tendency to drift upwards slightly (see Lee et al., 2004).

Preliminary letter-reading task

WS's ability to read random letters of the alphabet, printed at 32 point in upper or lower case and in various fonts (Times New Roman, Monotype Corsiva, Arial, and Tahoma) was also checked. WS was able to name these letters without

[9] The terms 'horizontal' and 'vertical' are henceforth used to refer to the long and short axes of the landscape page respectively. However, it should be noted that, since the page was presented on a tabletop, the 'vertical' axis was actually oriented in depth, parallel to WS' sagittal axis. These terms will be used with this meaning also in the following chapters.

hesitation, suggesting that this would constitute a suitable visual discrimination task for the experimental dual task to follow.

Experimental dual task

In the experimental task, WS was required to perform a straight-line drawing task and a letter-reading task simultaneously, using a similar set-up and scoring system as in the preliminary graphic copying task. On each trial, a sheet of A3 paper in landscape orientation was presented with a 6 mm diameter black dot, as before, centred vertically 63 mm from the left edge. Along the top or bottom of the sheet (35 mm from the top or bottom edge) was a row of random letters printed at 32 points in upper or lower case and in various fonts. There were either 10 or 20 letters, spaced evenly and spanning 63 mm from the left edge of the sheet to 63 mm from the right edge. In the 10 letters condition, the inter-letter spacing was 22 mm; in the 20 letters condition, the inter-letter spacing was 10 mm. On each trial, WS was instructed to draw a straight-line from the starting point to the right hand edge of the paper whilst naming any letters that her hand moved past. To assist with the reading requirement, the examiner pointed to each letter that the hand moved past. Two blocks of twelve trials were performed. In the first block, letter density was manipulated according to a repeating ABBA schedule, with the 10-letter condition first, and figure position alternated between trials, beginning with the figure at the top. This trial order was reversed in the second block.

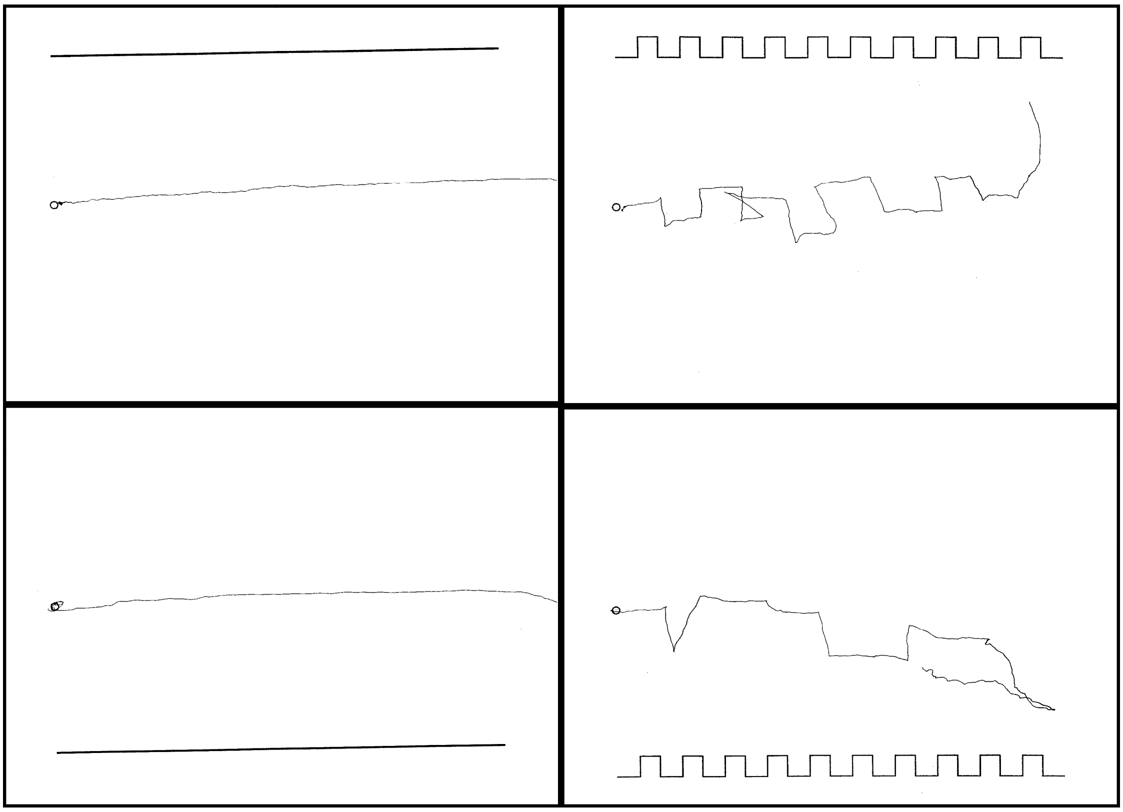
Results

Preliminary graphic copying task

Figure 4.3 shows representative examples of WS's performance in the preliminary graphic copying task. For the Luria's figure, she produced very poor reproductions that tended to close-in markedly toward the model. Unfortunately, during the first block of trials, WS became acutely distressed by her inability to copy the Luria's figure and requested to stop the task after only seven trials. Moreover, two of the attempted copies of the Luria's figure consisted of fragmented lines in various positions on the sheet (mostly near the model), from which no satisfactory measure of CIB could be derived, and these trials were considered void. This resulted in a total of seven lost trials from the first block. WS was more composed during the second block, completing all trials. In both blocks, WS experienced obvious difficulties with only the Luria's figure; she was always able to copy the simple horizontal line, with no visible tendency toward CIB.

Figure 4.3. Representative examples of WS's performance in the preliminary graphic copying task of Experiment 1, showing CIB for the more complex Luria's figure.

The examples selected are the individual trials in which the CIB score (deviation toward the model) was closest to the mean score in the corresponding condition.



Statistical analyses of mean deviations confirmed these impressions. One-way t-tests versus zero found that the mean deviation toward the model was not reliable for the simple model (mean = 1%, *SD* = 13), $t(9) = 0.25$, $p = .80$, but was reliable for the complex model (mean = 15%, *SD* = 12), $t(6) = 3.26$; $p = .017$. An independent t-test found that the difference between simple and complex conditions was reliable, $t(15) = 2.31$; $p = .035$. The ability to produce the straight line is important, as it establishes that WS understood the task instructions adequately, ruling out any explanation of CIB based on a simple misunderstanding of task instructions.

Analysis of the slope measurement produced different statistical outcomes. One-way t-tests versus zero found no reliable mean deviation toward the model for either the simple model (mean = .015, *SD* = .05), $t(9) = 1.02$, p=0.33, or the complex model (mean = .11, *SD* = .13), $t(6) = 2.22$, $p = .068$. An independent t-test found no reliable difference in slope between the simple and complex conditions, $t(7.07) = 1.83$, $p = .10$. However, the former measure of mean deviation was considered to be more representative of performance than the slope measure, the practical shortcomings of which will be considered in the Comment section.

Experimental dual task

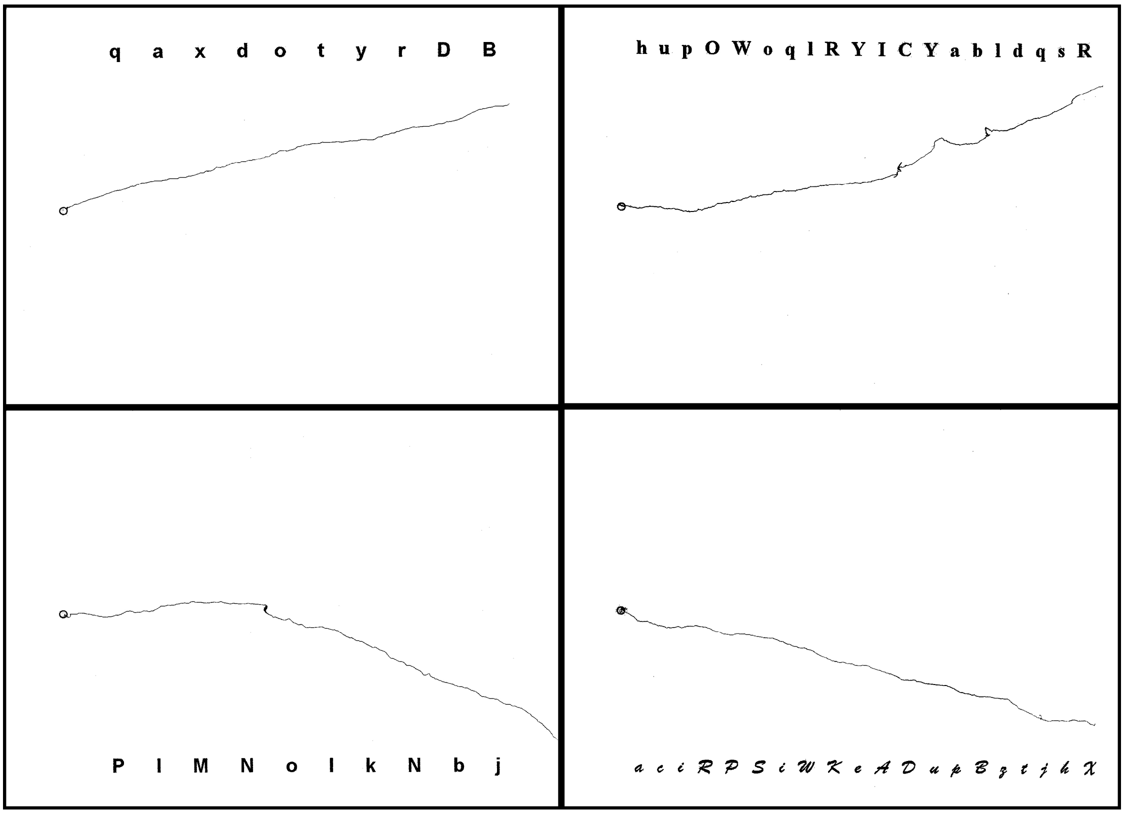
Figure 4.4 shows representative examples of WS's performance in each experimental condition for the dual task. WS's drawn line veered toward the letters read on every trial, and this was not obviously affected by the density of the letters.

Statistical analyses were performed on the mean deviations and slopes of WS's drawn lines. One-way t-tests versus zero found that the mean deviation toward the letters was reliable for both the 10-letter (mean = 33%, *SD* = 18), $t(11) = 6.22$, $p < .001$, and 20-letter conditions (mean = 31%, *SD* = 14), $t(11) = 7.49$; $p < .001$. An independent t-test found no reliable difference between these conditions, $t(22) = .17$, $p = .86$.

Similar results were found in the analyses of slope. The mean slope of the line drawings was reliably greater than zero for both the 10-letter (mean = .21, *SD* = .11; $t(11) = 6.41$, $p < .001$, and 20-letter conditions (mean = .21, *SD* = .06), $t(11) = 10.69$, $p < .001$]. An independent t-test found no reliable difference between these conditions, $t(22) = .22$, $p = .82$].

Figure 4.4. Representative examples of WS's performance in the dual task of Experiment 1, showing pronounced veering toward the letter stimuli in all conditions.

The examples selected are the individual trials in which the CIB score (deviation toward the model) was closest to the mean score in the corresponding condition



Performance of WS and control group

Ten older participants (5 males and 5 females; age range 63-71 years old) were asked to perform the present experimental task (see also Chapter 5). In order to compare WS and control performances, a Crawford & Howell modified t-test was carried out on the line drawings mean deviation from the horizontal (see Table 4.1). In the preliminary coping task, the analysis showed that WS performance differed from the control when the model was presented on the top, while no significant difference was found when the line was presented on the bottom. In the dual task condition, the performance of WS strongly differed from the control group in all the conditions. Therefore, this analysis confirmed the previous observations, that the WS performance exhibited in experimental dual task was abnormal and mimicked CIB in graphic copying.

Table 4.1. Mean and *SD* of WS and controls in preliminary and experimental tasks, and Crawford & Howell modified t-test

Condition	WS Mean and *SD*	Controls Mean and *SD*	T-test
Preliminary graphic copying task			
Line copy top	14.38 (7.52)	2.90 (3.52)	$t(9) = 3.10$, $p < .05$
Line copy bottom	7.04 (8.07)	2.38 (2.49)	$t(9) = 1.78$, $p = .10$.
Experimental dual task			
Low Density top	44.08 (9.09)	5.09 (2.52)	$t(9) = 14.75$, $p < .000$
Low Density bottom	-27.06 (23.94)	1.60 (3.27)	$t(9) = -8.35$, $p < .000$
High density top	31.72 (15.67)	3.75 (1.95)	$t(9) = 13.67$, $p < .000$
High density bottom	-36.58 (17.82)	3.57 (2.63)	$t(9) = -19.63$, $p < .000$

Comment

Some relevant methodological issues relating to the assessment and quantification of CIB are raised by the outcome of Experiment 1. Like Lee et al. (2004) 'Luria' figure, composed of sequential sub-elements, were used for the assessment of graphic CIB. These are readily amenable to manipulations of task complexity, via modulation of the variety and/or predictability of sub-elements. Additionally, since the figures are laterally extensive, they allow CIB to develop over time, and its evolution is recorded along the left-right axis. Lee et al. (2004) measured the vertical coordinate of the copy at 2 mm intervals along the horizontal axis, with the slope of the regression line between these providing their index of CIB.

In the present Experiment 1, this measure proved less sensitive to CIB than was a simple estimate of the mean vertical coordinate.

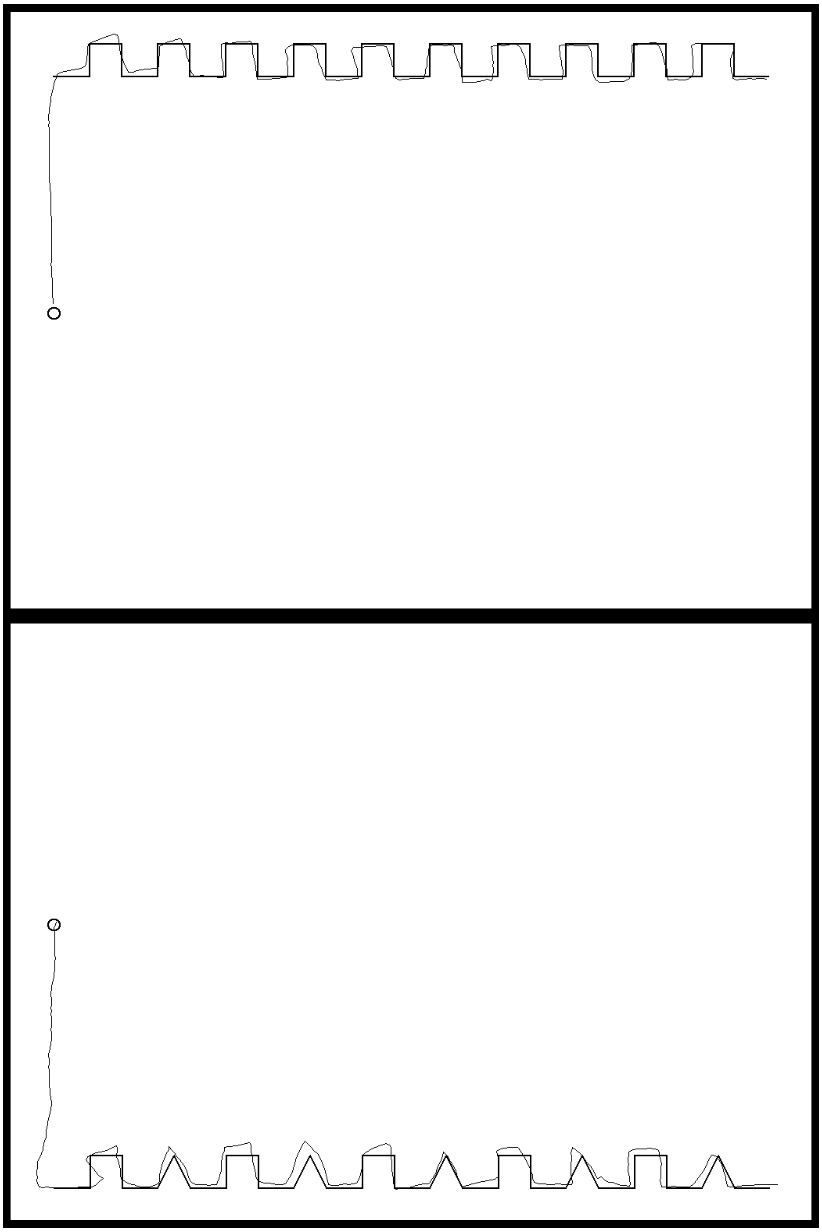
One problematic aspect of the slope measure, which may account for its reduced sensitivity, is that it assumes a linear migration of the copy, and one that does not reach a ceiling level of proximity to the model, an assumption that does not always hold. Whilst patient WS often did show strongly linear manual migration (median r^2 in Experiment 1 dual task = .94), this relationship was sometimes depressed (r^2 < .90 in 33% of trials) by an initial period of stability or a terminal ceiling level of proximity. In one trial, there was a clear indication of severe CIB followed by corrective migration away from the model, which seriously disrupted the slope measure (r^2 = .42). The average vertical coordinate is therefore believed to provide a more robust measure of CIB, applicable across a wider range of behaviour.

It is notable that Lee et al. (2004) excluded from their study AD patients in whom early ceiling levels of CIB were observed on Luria's task. Similarly in the present study, patients in whom the migration toward the model is almost immediate were encountered (see Figure 4.5). Whether such extreme, 'instant' CIB reflects a difference of degree or quality from the more gradual migration reported in the present study is a matter for future investigation. Future studies should also explore whether the attraction hypothesis can account for the tendency to trace the contour of the model, or if this behaviour represents a different form of CIB. For instance, as shown in Figure 4.4, in order to perform the copying task the patient converts the graphic copying into tracing. As predicted by the compensation hypothesis, the patient could use this tracing strategy to overcome visuospatial or working memory deficits. Therefore, future research should experimentally examine the two hypotheses of CIB for this tracing behaviour.

A further methodological consideration is the use, in the present design, of models placed both at the top and at the bottom of the copying sheet. In testing for CIB, it is essential to vary the position of the model in order to confirm that any migratory effects are specifically model-directed. For instance, the healthy control sample reported in Lee et al. (2004) showed a subtle but reliable tendency to move up the page, which was interpreted as migration toward the model. Unfortunately, since the model was always positioned at the top of the page, this interpretation cannot be distinguished from the possibility that the healthy subjects had a default tendency to drift upward regardless of position of the model. In principle, a similar uncertainty pertains to the behaviour of Lee et al.'s (2004) AD group, though the present results strongly endorse their interpretation of the observed migrations as CIB. Moreover, in the present study, the performance of the control group confirmed that an upward deviation of the graphic copying can be observed independently from the model position. Similar evidence was found on the dual task condition, where elderly adults' line drawing migrated toward the top of the sheet in both conditions: when the letters were presented on the top or on the bottom of the sheet of paper.

Figure 4.5. Illustrative examples of 'instant' CIB, with immediate migration toward the model, followed by tracing of the model contours.

These copies were produced by a 60 year old woman with moderate VaD (ACE score = 74/100).



EXPERIMENT 2: CIB IN GESTURAL TASKS

Procedure

Preliminary gesture imitation task

Patient WS was asked to copy simple unimanual gestures with her right hand. For this assessment, a 64 × 46 cm piece of paper was placed on the table in front of WS, so that the centre of the paper was in line with the her right shoulder. The paper was divided by thick black lines into five horizontal sections. A central section of 16 cm defined WS's workspace. Two sections of 8 cm at the left and right edges of the paper defined the examiner's workspaces, which were separated from WS's workspace by intermediate spaces of 16 cm. The examiner sat alongside WS, to the right or left. Prior to each trial, it was emphasised that WS should make her gestures within her own workspace. The examiner then began a sequence of 20 gestures. The sequence began with the right hand touching the left shoulder, after which the hand was brought to the table as a gesture, and then returned to the left shoulder. Patient WS was required to copy the examiner's movements step-by-step. On each trial, the same gesture was repeated 20 times, and was either simple (palm down) or complex (fist down with index and middle fingers in a 'V' configuration). Two blocks of four trials were performed, one before the experimental task (see below), and the other after it. In the first block, gesture complexity was manipulated according to a repeating ABBA schedule, with the simple gesture first; and the examiner's position alternated between trials, beginning with the examiner to the right of the patient. This trial order was reversed in the second block.

Performance of this task was recorded by a video camera, facing the table. Prior to the experiment, a calibration sheet was laid over the experimental sheet. The calibration sheet was divided into seven sections: WS's central workspace (16 cm) with three further 8 cm sections to either side. On each side, the three outer sections were numbered from 1 to 3, from inner to outer. For each trial, each gesture was scored according to the number of the section that it was made in, with deviations toward the model signed positively and deviations away from the model signed negatively. If the gesture overlapped a dividing line between sections, then the average number of the two adjoining sections was awarded. The average gesture location for each trial was calculated across the 20 gestures, and this value was expressed as a percentage of the maximum possible closing-in score of 3. In addition, each gesture was scored for accuracy of reproduction using the scale of 0-2 (see screening tasks).

Preliminary letter-reading task

WS was asked to read random letters of the alphabet, printed individually, at 32 point font, in upper or lower case Arial font on cards (5.7 x 4.3 cm). A first (simple) set of letters was printed normally, whilst a second (complex) set was made more difficult to discriminate by the overlay of a 70% random noise mask. WS was able to name letters from the first set without hesitation or error, but letters from the second set only with close scrutiny and occasional errors. This reading task, with two levels of difficulty, was used as a secondary task in the experimental dual task to follow.

Experimental dual task

In the experimental task, the same set-up and scoring system was used as in the preliminary gesture imitation task. In this case, however, WS was required to perform a simple repeated gesture (palm down) from memory, and simultaneously to perform a card reading task. On each trial, the examiner sat to WS's left or right and placed 20 cards sequentially in the examiner's workspace on that side. WS was required to read each card aloud, whilst simultaneously making the simple palm-down gesture within her central workspace. Prior to each trial, it was emphasised that she should always place her hand within her own workspace, and that she should try to synchronise her gesture with her reading of the card. Two blocks of four trials were performed. In the first block, the complexity of the reading task was manipulated according to a repeating ABBA schedule, with the simple set of letters first, and the examiner's position alternated between trials, beginning with the examiner to the right of the patient. This trial order was reversed in the second block.

Results

Preliminary gesture imitation task

In the gesture imitation task (Figure 4.6), the average quality of WS's gestures was reliably higher for the simple than for the complex gesture (mean rating 1.95 vs. 1.18), $t(6) = 2.70$, $p = .03$. In terms of response location, patient WS deviated toward the examiner's model gesture in 58/71 movements for the simple gesture (mean deviation = 19%, $SD = 17$), and 78/83 movements for the more complex gesture (mean deviation = 62%, $SD = 18$). A one-way t-test confirmed that the bias toward the model was reliable overall, $t(7) = 4.12$, $p = .005$, and an independent t-test found that the bias was reliably greater for the complex gesture, $t(6) = -3.37$, $p = .015$.

Figure 4.6. Representative examples of WS's performance in the gesture imitation task of Experiment 2, showing good quality reproduction with relatively mild CIB for the simple gesture (upper panels), and poor reproduction with more severe CIB for the complex gesture (lower panels).

The examples selected are individual movements in which the CIB score (deviation toward the model) was closest to the mean overall score in the corresponding condition.

Experimental dual task

Figure 4.7 shows representative responses for each condition in the dual task. WS's gestures deviated toward the letter-cards read on all 80 movements for the simple letters (mean deviation = 85%, *SD* = 19) and on 65/80 movements for the complex letters (mean deviation = 48%, *SD* = 59). A one-way t-test confirmed that the average bias toward the letter-cards was reliable overall, $t(7) = 4.15$, $p = .004$, and an independent t-test, with degrees of freedom adjusted for unequal variances, found no reliable difference between the average bias for simple and easy cards, $t(3.59) = 1.20$, $p = .30$. In both conditions, there was a strong tendency to show CIB. Indeed, in 97/160 movements overall, WS actually placed her hand on top of the cards (her occasional apologies when she did so indicate that she understood this to be an error).

Figure 4.7. Representative examples of WS's performance in the dual task of Experiment 2, illustrating mild (left panels) and extreme (right panels) examples of CIB toward the letter cards, for both simple (upper panels) and complex letters (lower panels).

Comment

WS's motor behaviour, which was characterised by a veering toward the focus of visual attention, is clearly different from other motor misbehaviours, including 'magnetic' (or frontal) apraxia (Denny-Brown, 1958) whereby patients with frontal lesions fail to inhibit their grasp of felt objects, 'utilization behaviour' (Lhermitte, 1983) which defines the compulsive use of objects on sight, and 'anarchic hand' (Della Sala, Marchetti & Spinnler, 1994) which is characterised by unwanted, goal-directed actions performed with one hand, often at cross purposes with the other hand.

The manual attraction observed in CIB must also be distinguished from 'magnetic misreaching' toward fixation, in which affected patients required to reach to a target in extrafoveal vision reach slavishly for the fixation point instead (Carey, Coleman, & Della Sala, 1997). This sign, which is characteristic of optic ataxia, has been postulated to reflect a primitive coupling of hand and eye released from inhibition following posterior parietal lobe damage (Milner, Dijkerman, McIntosh, Rossetti, & Pisella, 2002). A similar default coupling may underlie CIB, but in this case its appearance does not reflect a general difficulty in responding away from fixation, since the present screening tests excluded optic ataxic misreaching. Rather, the manual attraction may be toward the focus of attention, as required by visual analysis of the model in a copying task, or letter reading in the present dual tasks.

The above proposal is consistent with the view that attention-attracting visual stimuli recruit motor programs automatically, which must be suppressed continuously to prevent the disruption of ongoing behaviour (e.g. Tipper, Howard, & Houghton, 1998). Subsequent to data collection, it was observed informally that WS's manual activity could also be drawn toward an *irrelevant* distracting stimulus: her gesture production migrated toward a strip of reflective paper, crinkled by the examiner's hands. This observation, though anecdotal, suggests that CIB can arise for exogenously-created, as well as endogenously-defined attentional foci.

GENERAL DISCUSSION

This study compared the compensation and attraction hypotheses of CIB in a patient with moderate AD. The important empirical outcomes were straightforward. In both graphic and gestural copying tasks, a critical role of model complexity was confirmed, with no sign of CIB for very simple stimuli, and pronounced veering toward more complex models. This effect of figure complexity replicates the results obtained with a large cohort of patients with AD (see Chapter 3) and previous reports (Lee et al., 2004; Mayer Gross, 1935; Muncie, 1938) but, in itself, is compatible with either the compensation or attraction hypotheses. However, when graphic or gestural production was combined with an unrelated visual discrimination, manual performance migrated toward the visual stimuli, precisely mimicking CIB for copying. This migration cannot be understood as a strategic compensation for visuospatial or memory dysfunction, since the visual stimuli offered no information of relevance to the manual task. Rather, manual performance may be drawn toward any sufficiently absorbing focus of visual attention, as predicted by the attraction hypothesis of CIB.

These results confirm that CIB is a rather general phenomenon, not exclusive to copying tasks, but one that can be elicited, perhaps, by any task requiring visual analysis at one location and motor production at another. The convergent results of the graphic and gestural experiments support the view that a common mechanism underlies the various task-specific manifestations of CIB.

Testing experimentally between attraction and compensation hypotheses is a critical first step in explaining CIB. A limit of the present study is that the experimental design directly tested the attraction hypothesis, while null results were predicted by the compensation hypothesis. Future studies should be designed to specifically test the compensation hypothesis. For instance, one possible method of testing this hypothesis could be to manipulate the distance between the model and the starting point of the copy and to explore if this manipulation has an effect on the accuracy of the copy. As discussed in Chapter 2, both attraction and compensation hypotheses would predict an increase of CIB when the model is placed at a larger distance from the starting point of the copy. However, the compensation hypothesis would further predict an improvement in the accuracy of the copy performance, with the decrease of the distance between the model and copy. Since this hypothesis considers CIB as a compensatory strategy, used to overcome visuospatial and/or working memory deficits and to perform the copying task, it does predict an improvement of the copying performance with the decrease of the spatial distance between model and copy. On the contrary, the attraction account would not predict any improvement of the accuracy with the manipulation of the distance.

Morever, the present results must be considered in relation to the type of CIB observed in this patient, consisting in a progressive migration towards the model. As previously stated, it is possible to speculate that the compensation hypothesis might account for a different form of CIB, characterised by the tendency to trace the lines of the original model.

Having rejected the compensation hypothesis, the next challenge is to further specify the attraction hypothesis. Kwon et al. (2002) have suggested that the manual attraction in CIB is precipitated by a deficiency of executive and/or attentional resources (see also Gainotti, 1972; Lepore et al., 2005). The production of an appropriate copy from a model, in addition to its visuospatial and memory demands, requires the efficient division, or switching, of attention between model analysis and copy production. Task breakdown in CIB could thus plausibly result from the impaired disengagement of focused attention from the model, or from an impaired ability to divide attentional resources between the two sub-tasks, which might relate to the specific deficit in dual task coordination that has been found in AD (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991; Della Sala, Baddeley, Papagno, & Spinnler, 1995; Logie, Cocchini, Della Sala, & Baddeley, 2004; MacPherson, Della Sala, Logie, and Wilcock, 2007). An important function for executive control would be to inhibit ongoing analysis of the model to allow monitoring of copy production. Evidence that inhibitory functions are impaired in AD is overwhelming (Amieva, Phillips, Della Sala, & Henry, 2004).

Inadequate manual monitoring may be more likely when the visual task is complex, and would release the default tendency of migration toward the attentional focus. In this context, it should be emphasised that any increase in the difficulty of the visual task should increase the likelihood of CIB, whether the difficulty derives from the task itself, or from cognitive factors that render a patient less able to perform a task. Thus, it might be expected that visuospatial deficits and/or working memory impairments (as noted in WS's neuropsychological profile) would promote CIB by increasing the subjective difficulty of copying tasks. This mechanism would predict that an overall association between visuospatial impairments and CIB might exist, even though the primary critical factor would be the depletion of executive resources.

The above suggestion is speculative, and considerable work will be required to test and refine the hypothesis. However, some initial supportive evidence has been obtained in the large cohort study of patients with AD presented in the previous chapter. For instance, in this group of patients, the performance on the attention subtest of the MODA was the unique predictor of the near type of CIB, while attention and visuospatial abilities were both responsible for the overlap type of CIB. Nonetheless, further evidence can be gleaned from the literature. Septien et al. (1992) reported two cases of frontal-syndrome associated with intractable epilepsy, one of whom exhibited CIB as a prominent symptom. Similarly, Hernandez et al. (2002) found that errors (including CIB) in the copying of Luria's figure were more frequent in children with frontal lobe epilepsy than in those with temporal lobe or generalised epilepsy. Additionally, Lepore et al. (2005) reported the case of a man with a right frontal infarct, who showed CIB in copying geometric figures, and mislocated numbers in clock-copying, always in the direction of the model, despite accurate placement when drawing from memory. The authors attributed these effects to a lack of frontal inhibitory mechanisms. CIB in clock-copying was also studied by Cosentino et al. (2004), who found it to be associated with a higher number of white matter lesions and poorer performance on executive frontal tasks, in patients with mild dementia.

To conclude, CIB, by providing one route to failure on copying tasks, has long been regarded, by definition, as a form of CA (e.g. Critchley, 1953; Grossi & Trojano, 1999; Mayer Gross, 1935). The present findings show that the phenomenon is not specific to copying tasks, though such tasks may most commonly elicit it in clinical examinations. Whilst the diagnostic label of CA is often taken to imply posterior, especially parietal neuropathology, CIB might actually be more characteristic of attentional/executive deficits associated with frontal lobe dysfunction.

It might be argued that the results of the present study could be related to the specific nature of CIB in this patient and therefore confined to this single case study. For this reason, in the next chapter a study with a group of patients with AD will be presented. The aim of this study was to replicate the present results in a group of patients with AD. Therefore, this cohort was been presented with the present line drawing experiment. Since the mean vertical deviation from the centre of the sheet of paper has been demonstrated to be a more sensitive measure of CIB than the slope, this scoring procedure was applied in further studies (see Chapter 4, 7 and 8).

CHAPTER 5
Further examination of Closing-in behaviour in Alzheimer’s disease

INTRODUCTION

The present study aimed to replicate in a larger sample of patients with AD the results obtained in the single case study, reported in Chapter 4. In that patient, affected by moderate AD, who showed CIB in figure copying and gesture imitation, the two competing hypothesis of CIB (Lee et al., 2004) were tested experimentally using a dual task paradigm. The patient was presented with two different tasks: a straight-line drawing task in conjunction with a secondary letter-reading task and a gesture performance task in conjunction with a secondary letter-reading task. In both tasks, the patient performance veered markedly toward the location of the letters attended (top or bottom of sheet in the line drawing task; right or left of the surface in the gesture performance task). This evidence is supportive of the attraction hypothesis of CIB (Lee et al., 2004), which conceives CIB as a manual bias toward the point of attention. The findings further demonstrate that CIB is not specific to copying tasks, as the compensation hypothesis predicts (Lee et al., 2004) although it might be commonly elicited by them.

The original design of the present study included two experiments. The first experiment aimed at assessing the cognitive nature of CIB in patients with AD. This experiment would have encompassed the aims of Chapter 3, by applying a customized battery of neuropsychological tasks for the specific assessment of constructional abilities and CIB, visuo-spatial analysis, working memory, and executive functions. The second experiment used the dual task procedure to assess whether the results of the single case study can be generalized to a larger group of patients with AD. This study would have aimed to replicate and expand the results obtained in patients with AD, in Chapter 3 and 4, to a large sample of patients. It was originally planned to test four patient groups with AD: patients with CIB and no CA; patients with CA and no CIB; patients with CA and CIB; and patients without CA or

CIB. The study, as planned, would have increased the understanding of the relationship between CIB and CA, pointing at examining the possible dissociations between the two symptoms. However, several practical limitations impeded the study as planned. First, it took more than one year to receive full ethical approval for the study. Second, once the ethical approval was obtained, the recruitment proved to be very slow. Over a period of one year, only eleven patients were found. Of these eleven patients, one withdrew from the study and four did not meet the inclusion criteria. Therefore, the final comprised only six patients, with mild AD, none of whom showed CIB. Because of these problems, the neuropsychological battery was used simply as a basic assessment, rather than as a full experiment in its own right. The data from Experiment 2 were analysed as a series of single case studies as well as a small group study. Patients' performance was compared with that of ten controls. Although it is worth reporting this study as part of the present thesis, the results should be interpreted with cautition, because of the small sample size, the mild severity of AD, and the absence of CIB in the patient sample.

MATERIAL AND METHODS

Participants

Eleven patients with AD were recruited from the Royal Victoria Hospital Memory Clinic in Edinburgh over a period of two years. One patient decided to withdraw from the study and did not complete the testing sessions. Of the remaining ten patients, four patients did not meet the inclusion criteria, obtaining a MMSE score above 24, and were hence excluded from the analyses.

The inclusion criteria were:

1. A clinical diagnosis of AD following the criteria of McKhann et al. (1984)
2. An overall score ≤ 24 in the Mini Mental State Examination (Folstein et al., 1975)

The final sample was composed of six patients (3 men and 3 women), with a mean age of 84 years (*SD* = 4.3) and mean years of education of 12.9 (*SD* = 4.7). The total testing time, per patients, was two hours, and testing took place in one session.

Ten (5 men and 5 women) healthy volunteers (mean age 67.8, *SD* = 2.3) were recruited from the volunteers' panel of the University of Edinburgh. This group was asked to perform the dual task experiment and some cognitive tasks (constructional tasks, Sustained Attention Task, and the Battery for Visuospatial Abilities).

This study was approved by the NHS Lothian Research Ethics Committee (reference number: 07/F1102/55) and informed consent was obtained from the all participants.

Screening tasks

Participants were presented with a customized battery of neuropsychological tasks for the assessment of dementia, CIB and CA, visuo-spatial abilities, working memory, attention and executive functions.

General cognitive status

General cognitive status was assessed with the ACE (Mathuranath et al., 2000). The ACE is a brief cognitive battery for the assessment of dementia, which comprises the cognitive subtests of the MMSE. Therefore, the MMSE score was calculated in addition to the ACE overall score.

Assessment of CIB and CA

CIB and CA were assessed using three geometrical shapes copying tasks, presented in order of increasing complexity: a square, two overlapped squares and a cube. Each stimulus was 40 mm × 40 mm in extent and presented in the centre of the left half of an A4 sheet in landscape orientation. Patients were asked to perform the copy of the shape, without any specific instructions regarding the position of the graphic copying.

CIB was rated on a 0-2 scale, according to the following descriptors

0: Overlap-type CIB. The copy touches the edge of model at one or more points, or partially or wholly overlaps the model.

1: Near-type of CIB. The copy is performed very close to the model (< 10 mm shortest distance[10]).

2: No CIB. The copy is well-separated from the model (> 10 mm shortest distance).

CA was scored using a 0-2 point scale:

0: Severe CA. The copy is unrecognisable.

1: Moderate CA. The copy is not accurate, but the model is partially recognizable.

2: No CA. The copy is well executed, with no gross distortions of scale.

CIB and CA were further assessed by executing a copy of a laterally extended model (*Alternated Square Pentagons and Triangles* Luria's figure) placed on the top and on the bottom of an A4 paper. This picture is composed of 5 squares, 5 triangles, and 5 pentagons, presented in a fixed predictable sequence. Each of these elements was 10 mm long and 10 mm high, and the line connecting adjacent elements was 5 mm long. The figure was presented along the top (12 mm from the top edge) of an A4 paper in landscape orientation. The starting point of the copy was specified by a 5 mm line centred vertically (80 mm below the model) 31 mm from the left edge of the page. Patients were asked to perform the graphic copying starting with the pen on the top of the line. CA score applied in the task was the same as for the geometrical shapes copying task. Instead, CIB was scored in Luria's picture as follows:

0: Overlap-type CIB. The copy partially or wholly overlaps the model.

1: Near- type of CIB. The copy touches or comes very near to the model at some point (< 10 mm shortest distance).

2: No CIB. The copy is well-separated from the model (> 10 mm shortest distance).

Further neuropsychological assessments

Visuo-spatial abilities were assessed using six subtests of the Battery for Visuospatial Abilities (BVA; Angelini, Correra, Callise, D'Auria, & Grossi, 1993).

[10] As stated for the definition of this type of CIB used in Chapter 3, the present operational definition of the near-type CIB as within 10 mm is arbitrary but aims to provide a more objective criterion

Patients were asked to discriminate the length (4 trials) and inclination (4 trials) of lines, the position of points inside a square (4 trials), orientation of angles (4 trials), complex multipart shapes (4 trials), and hidden geometrical shapes (4 trials). In each task, the patient was presented with a target on the left and four possible matches on the right. The patient was asked to identify the test item that matches the target. One point was given for each correct answer for a maximum total of 24 points.

Working memory was tested using the Corsi Blocks-Tapping Test (Corsi, 1972) of the Weschler Memory Scale Third Edition. The patients were asked to repeat the sequence of blocks tapped by the examiner in the same order forwards. Sequences of the same number of blocks were presented two times, beginning with two blocks. Patients had a maximum of two attempts to correctly reproduce the series of blocks of the same length. One point was given for each sequence of blocks correctly reproduced up to a maximum score of 16.

The ability to hold visual information in memory was assessed using the recall version of Shapes and Names subtests of the Doors and People test (Baddeley, Emslie, & Nimmo-Smith, 1994). In the verbal recall of the People test, patients were presented with photographs of four people and were asked to remember their names and occupations. Then, patients were asked to recall immediately the name of the four people based on their occupations. A maximum of three points was given if the patient can recall the first name, the second name, and the correct association of both for each person (maximum overall score= 12). Each patient performed three trials, consisting in the pictures presentation and the immediate recall of the names (maximum total score of 36). After a time delay (between 10-15 minutes), patients were asked to recall the names of the four people without seeing the picture. One trial was performed and the scoring procedure was the same as for immediate verbal recall (maximum score of 12). The overall recall score of the People test was the sum of scores of immediate and delay recall (maximum score of 48).

The visual recall of the Shape test was similar to the People test. Patients were presented with four shapes and asked to memorize them. Then, patients were asked to draw the four shapes from memory on an A4 sheet of paper. A maximum of three points was given for each shape correctly reproduced (maximum overall score= 12). Each patient performed three trials, consisting of the presentation and drawing from memory of the shapes (maximum total score of 36). After a time delay (between 10-15 minutes), patients were asked to draw the shapes from memory again (maximum score of 12). The overall recall score of the Shape test consisted of the sum of scores of immediate and delay recall (maximum score of 48).

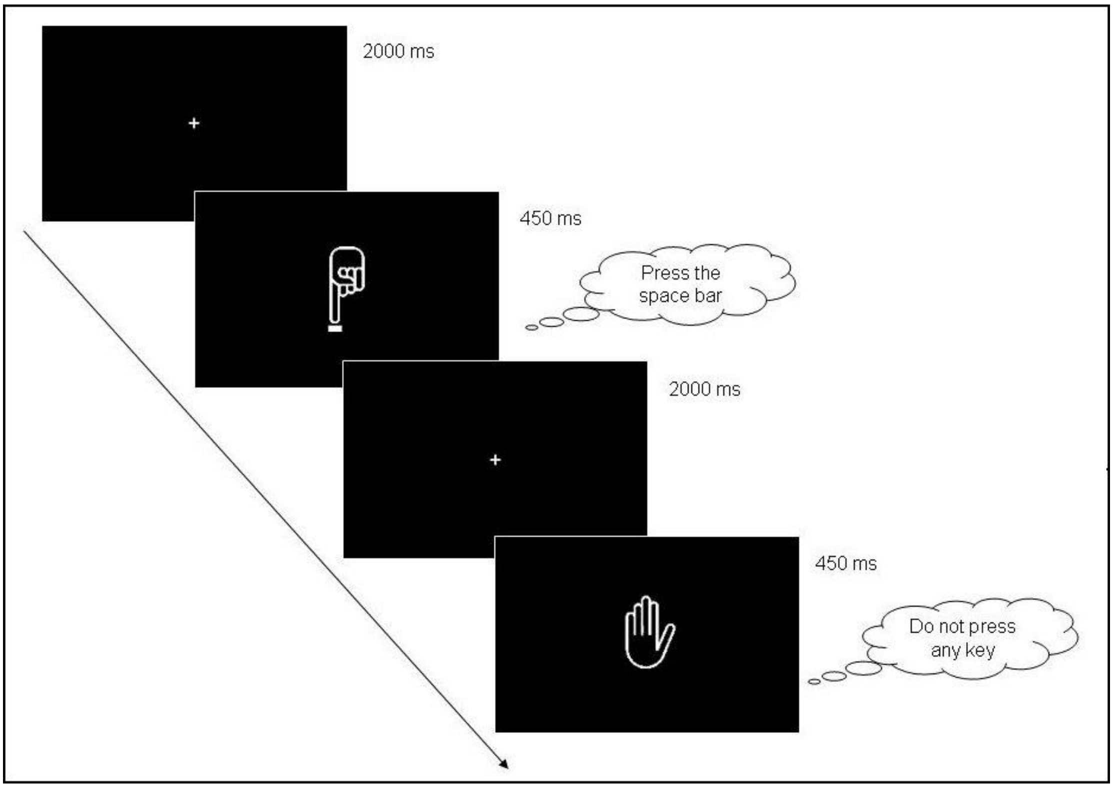
Executive functions were assessed using the Frontal Assessment Battery (FAB; Dubois, Slachevsky, Litvan, & Pillon, 1967). This brief battery comprises 6 subtests: similarities, lexical fluency, motor series, conflicting instructions, go-no-go task and reflex grasping behaviour. The similarity subtest assesses the ability to understand the association between two objects of the same semantic category, i.e., banana and orange. This subtest is composed of three trials and one point is given for each correct answer (max score 3). The lexical fluency subtest assesses the ability to generate words beginning with the letter *s* in 60 sec. The patient is given a score from 0 (less than 3 words) up to a maximum of 3 (more than 9 words). In the motor series subtest, the patient is asked to imitate and then reproduce Luria's motor sequence *fist-edge-palm* (Luria, 1966). A maximum score of 3 is given when the patient correctly reproduces the sequence six times (three imitations and 3 reproductions). In the conflicting instructions subtest, the patient is required to follow a verbal command, giving an opposite response to the examiner's alternating signal (i.e. to tap once when the examiner taps twice and vice versa). The patient is given a score from 0 (the patient imitates the examiner at least 4 times) up to a maximum of 3 (correct performance). In the go-no-go task, the patient is presented with a similar task as the previous subset (e.g., tap once when the examiner taps once), but then he is required to inhibit a learned response (not to tap when the examiner taps twice). A maximum score of 3 is given when the patient performs 10 trials correctly. The final task assesses the presence of reflex grasping behaviour. The patient is asked not to take the examiners' hand, although the examiner touches the patient's hand. A maximum score of 3 is given if the patient does not exhibit the reflex grasping behaviour.

Finally, selective attention, sustained attention, and attention switching were assessed. Selective attention was tested using the *Map Search* subtest, version A, of the Test of Everyday Attention (Robertson et al., 1994). In this task, the patient is shown a symbol of a restaurant (fork and knife) and he is asked to search for this symbol in a map of Philadelphia city. The patient is asked to perform the task for one minute and then to swap pens, and continue the task for one more minute. One point is given for each symbol located in the map in one and two minutes (a maximum score 80).

Sustained attention was assessed using a modified version of the Sustained Attention to Response Task (SART Robertson, Manley, Andrade, Baddeley, and Yiend, 1997). The SART is a go-no-go type of task, which is highly correlated with performances in the sustained attention subtest of the Test of Everyday Attention (SART, Robertson, Manley, Andrade, Baddeley, and Yiend, 1997). In the present study, variations of the original test were applied in order to make the task suitable for AD patients. The stimuli consisted of two types of black and white stylised drawing of hands (35 × 82 pixels) representing the *button press* or the *stop sign* (see Figure 5.1). The stimuli were presented for 450 ms each in the centre of a black background (800 × 600 pixels) of a MAC OS laptop. The stimuli were followed by a fixation cross (10 × 10 pixels) displayed for 2000 ms. Patients were instructed to press the space bar of the laptop when the *button press* was displayed on the screen; while they were asked not to press any key when the stop sign was displayed. Patients were presented with a fixed-sequence of 120 trials. In 106 trials the *button press* was presented and the stop sign was displayed on 14 random occasions. The overall duration of the task was 294 seconds. Prior to the task, the patients practiced 18 trials (15 button press and 3 stop sign). The software used to prepare and run this task was E-prime version 1.5. Using this system, reaction time (RT) to the button press stimuli, the number of responses omitted, and the number of errors (such as patient pressed the space bar when the *stop sign* is displayed) were recorded.

Finally, the Trail Making Test, parts A and B, (Corrigan & Hinkeldey, 1987) was used as a measure of attention switching. In part A of the test, the patient is presented with a series of numbered circles, from 1 up to 25, printed on A4 paper and is required to draw a line connecting the circles following the numbers in ascending order. In part B of the test, letters from A to L are presented in conjunction with numbered circles (1-13) and the patient is required to connect the circles, swapping between connecting numbers and letters. The time required to complete Parts A and B individually are recorded. A measurement of the ability to switch between two sets of stimuli is obtained from the subtraction of the time to complete Part A from that to complete Part B.

Figure 5.1. Sustained Attention task used in this study



EXPERIMENT

Procedure

Preliminary graphic copying task

Participants were asked to copy a straight black horizontal line presented on A3 paper in landscape orientation. Each line was 340 mm long and 1 mm thick, and was presented 39 mm from the top or bottom edge of the paper. A 7 mm line was centred vertically 29 mm from the left edge of the page. The instruction was to copy the line from left to right as straight as possible, starting with the pen on the black dot. Each patient performed four trials, with position of the model manipulated according to an ABBA schedule, starting with the line at the top.

In this task, CIB was quantified as the average deviation of the draw line from the horizontal. This was estimated by averaging the vertical coordinates of the line at 10 mm to the right of the start position and at successive rightward increments of 10 mm until the right hand edge of the paper was reached or the drawn line was no longer present. The median deviation across trials was calculated for each condition.

Experiment with dual task procedure

In the dual task experiment, patients were presented with a straight-line drawing task in conjunction with a letter-naming task. The letters were presented on the top or the bottom of an A3 sheet (39 mm from the top or bottom edge) in landscape orientation. As in the preliminary task, a black line (7 mm) was presented in the left edge of the paper centred vertically. In the 'low-density' condition, ten letters were spaced evenly between 51 mm from the left and right edges of the sheet. In the 'high-density' condition, twenty letters were spaced evenly between 38 mm from the left and right edges of the sheet. The instruction was to start with the pen on the line, and to draw a straight line to the right hand edge of the sheet, naming any letter that the hand moved past. To assist with the naming task, the examiner pointed to each letter that the hand moved past. Each patient performed two blocks of 4 trials. In the first block, density was manipulated according to a repeating ABBA schedule, with the low-density condition first, and figure position alternated between trials, beginning with the letters at the top. This trial order was reversed in the second block and the order of the blocks was alternated between patients.

The scoring procedure for CIB in this task was the same as used for the preliminary task.

RESULTS

Neuropsychological assessment

As stated earlier, ten healthy volunteers were asked to perform the constructional task, the SART, and the BVA. Normality threshold cut-off points were then calculated using Crawford and Howell's formula (1998), with an alpha level of .05 (see Table 5.1).

Table 5.1. Mean, *SD* and Cut-off of patients' performance in CA, BVA and SART.

		Mean and SD	*Cut-off*
CA	**Geometrical shapes**	5.2 (.42)	4.38
	Luria's figure	2 (0)	2
BVA		20.22 (2.81)	14.80
SART	**Errors**	1.8 (1.54)	4.77
	RT press (ms)	467 (58.43)	579.39
	Omissions	1.4 (.96)	3.25

None of the six patients showed CIB in either the geometrical shape copying task or the Luria's figure copying task (see Table 5.2). One patient (P1) showed a normal performance in both copying tasks; two patients showed performances just below the cut-off point in both geometrical shapes copying task and Luria's figure (P2 and P3); one patient showed a mild impairment in the geometrical shapes copying task (P6); and one patient performed below the cut-off point in Luria's figure, but showed normal performance in geometrical shapes copying task (P4).

Overall, the patients' performance was significantly worse than controls in the BVT, z = -2.95, p = .001. In the SART, patients produced significantly more omissions than controls, z = -2.47, p = .014, but the RT was not significantly different, z = -1.13, p = .30. A trend toward significance appeared in the number of errors of the SART, z = -1.97, p = .054. In the CA score of the shape copying task, a trend toward significantly poorer performance in patients than controld was found, z = -2.38, p = .056. This was also true of Luria's task, z = -2.64, p = .075.

Table 5.2. Screening tasks

			P1	P2	P3	P4	P5	P6
	Age – sex - education		*78; F; 16*	*88; F; 11.5*	*81; M; 10*	*87; M; 11*	*86; M, 9*	*87; F; 9*
Dementia Assessment	**ACE**		73*	60*	40*	57*	45*	64*
	MMSE		22*	24*	18*	21*	16*	24*
CIB	**Geometrical shapes**		6	6	6	6	6	6
	Luria's figure		2	2	2	2	-	2
CA	**Geometrical shapes**		5	4*	4*	5	5	4*
	Luria's figure		2	1*	1*	1*	-	2
Visuospatial abilities	**BVA**		14*	9*	-	12*	15	11*
Memory	**DOORS AND PEOPLE**	**People**	0*	-	-	6*	0*	10
		Shapes	0*	-	-	10	0*	19
	CORSI		7	6	-	2*	7	5*
Executive functions	**FAB**		15*	-	-	6*	12*	16
Attention	**Map search**	**1 min**	-	12 (4)*	-	-	-	25 (9)*
		2 min	-	29 (7)*	-	-	-	48 (9)*
	Trail making test	**Part A** (sec)	47	-	-	170*	74	48
		Part B (sec)	156	-	-	502*	478*	421*
	SART	**Errors**	2*	10*	-	5*	-	2*
		RT press (ms)	307	1008*	-	749*	-	489*
		Omissions	13*	13*	-	33*	-	2*

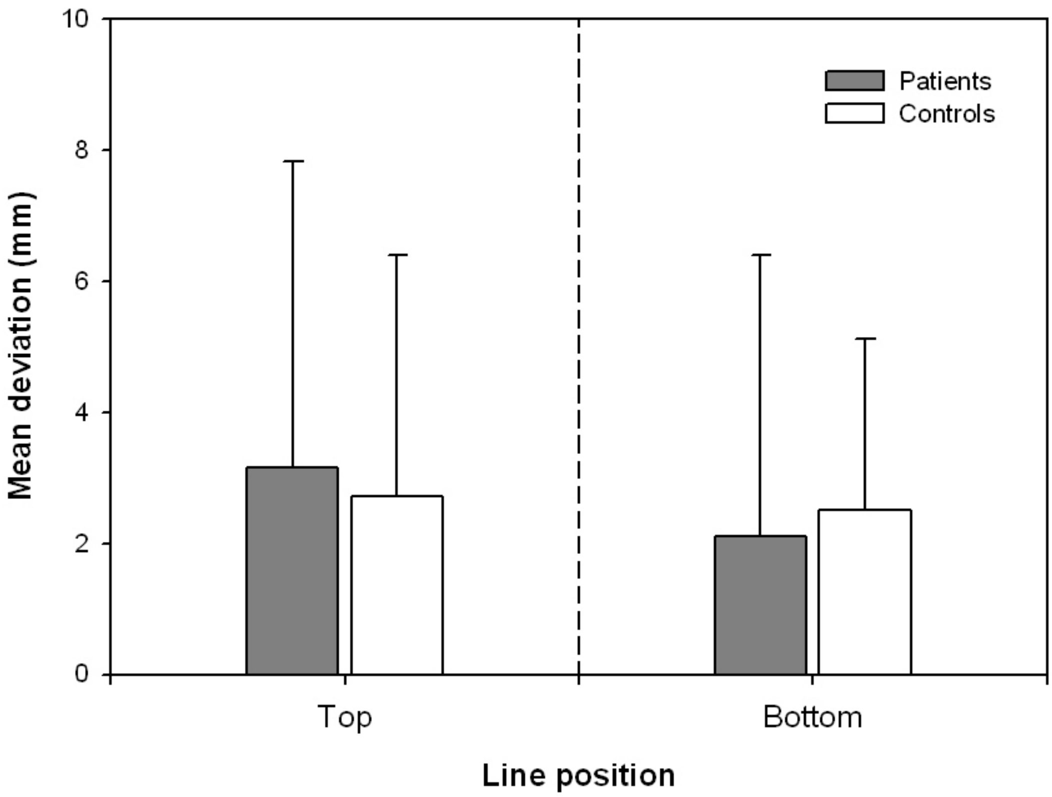
* Impaired performance; - not completed; () correct score

Experimental tasks

Preliminary copying task

Patients and controls showed similar performance in the preliminary line-copying task (see Figure 5.2): the line drawing deviated slightly toward the top of the sheet, both when the model line was placed at the top and at the bottom. In the patients group, this upward deviation did not differ when the model was at the top or at the bottom, $t(5) = 1.47$, $p = .20$. The same results were obtained for the control group, $t(9) = .08$, $p = .93$. In order to assess if the patients performance differed from the control, an independent sample t-test was conducted on the grand mean deviation of the line drawing from the horizontal (collapsed across model position). The analysis showed that the patients' performance in this task did not differ from the performance of controls, $t(14) = -.796$, $p = .43$.

Figure 5.2. Mean deviation and *SD* of patients' and controls' performances in the preliminary task.



Finally, in order to assess if the observed upward deviation was greater than zero, a one-sample t-test on the grand mean deviation (collapsed across groups) was performed. The analysis showed that the upward deviation was not reliably greater than zero, $t(15) = .746$, $p = .46$.

Since the patients' sample was very small, it was decided to analyse the data considering each patient as a single case study. A Crawford & Howell modified t-test carried out on the grand mean deviation to compare the performance of each patient against the norm scores derived from the control group (mean .035, *SD* 1.28) found that all the patients performed within the control limits in the preliminary task and in the experimental task (see Table 5.3).

Table 5.3. Grand mean deviation in preliminary task for each patient and Crawford & Howell's modified t-test.

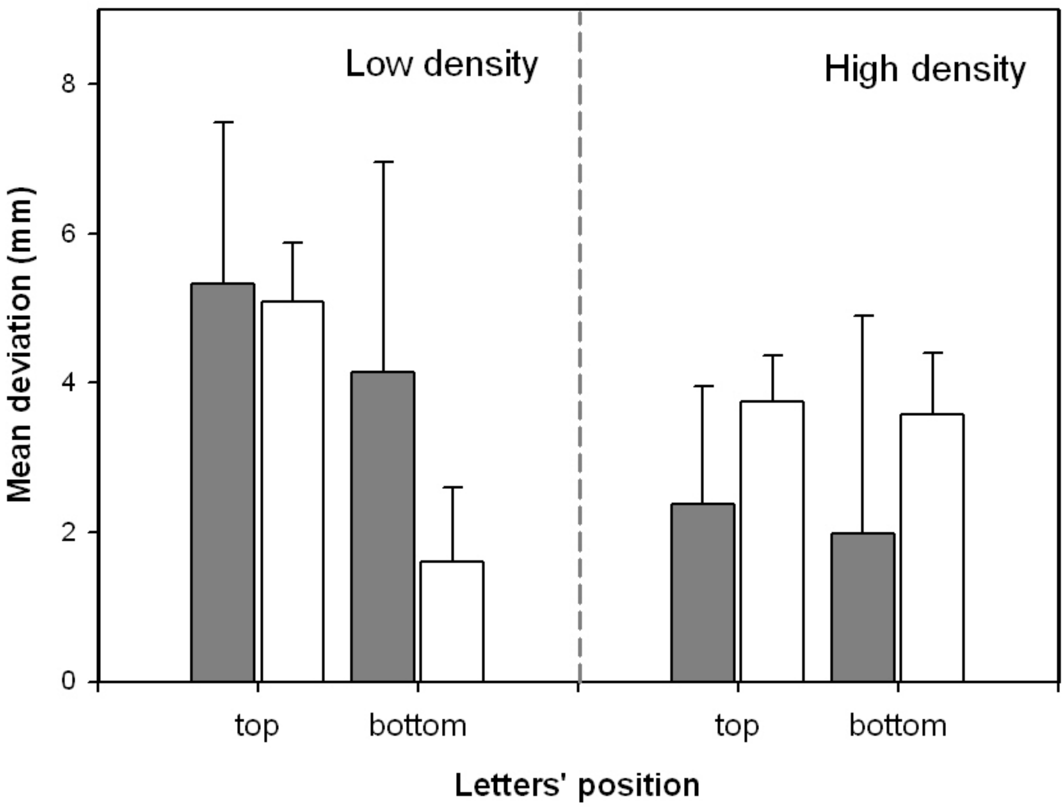
Patient	Grand Mean	T test
P1	1.37	$t(9) = 0.99$, $p = .34$
P2	1.30	$t(9) = .94$, $p = .37$
P3	1.38	$t(9) = 1.002$, $p = .34$
P4	-0.22	$t(9) = -0.17$, $p = .87$
P5	-0.95	$t(9) = -0.57$, $p = .58$
P6	.25	$t(9) = .08$, $p = .93$

Experimental dual tasks

In the experimental dual tasks, the patients' lines deviated slightly toward the top of the sheet, both when the letters were placed at the top and at the bottom, and with low and high density of the letters (see Figure 5.3). Similar upward deviation was observed in the performance of ten elderly subjects (see Figure 5.3).

Figure 5.3. Mean deviation and *SD* of patients' and controls' performances for each experimental condition.

The grey and the white bars represent the patients' and controls' performance respectively.



A mixed ANOVA, with group (patients and controls) as between subject factor and with density (low and high) and position (top and bottom) as within subject factors, was carried out on mean deviations of the line drawing from the horizontal. ANOVA showed that there was no main effect of group, $F(1, 14) = .001$, $p = .97$, and that the only significant result was the interaction between the density and the position of the letters, $F(1, 14) = 5.51$, $p = .034$. To further explore this interaction, a paired sample t-test was conducted on the mean deviation of the line drawing collapsed across the letters position. The analysis showed that the line drawing bias from the horizontal was higher in the low density condition than in the high density condition, $t(15) = 2.70$, $p = .016$.

Since patients and controls performed in a similar way in this dual task, in order to assess if the upward line bias was greater than zero, one sample t-test was conducted on the grand mean deviation collapsed across letters position and groups for the two density conditions. The line deviation in the low density condition was close to be significantly different than zero, $t(15) = 2.11$, $p = .052$, while non significant results were obtained for the high density condition, $t(15) = .23$, $p = .82$. This evidence suggests that a deviation toward the letter position was elicited in the low density condition in both patients and controls.

Following the same rationale as for of the preliminary copying task, Crawford & Howell's modified t-test was applied on the grand mean deviation toward the model position collapsed across density conditions to compare the performance of each patient against the control group (mean 1.74, *SD* = 1.73). Only one patient (P4) showed an abnormal performance compared to the control group (see Table 5.4), showing a deviation away from the letter position. However, since the alpha level was not adjusted for multiple comparisons, the abnormal performance in this patient in this task could be due to chance.

Table 5.4. Grand mean deviation in experimental task for each patient and Crawford & Howell's modified t-test.

Patient	Grand Mean	T test
P1	-1.28	$t(9) = -1.66$, $p = .13$
P2	-1.95	$t(9) = -1.60$, $p = .07$
P3	2.71	$t(9) = .53$, $p = .60$
P4	-3.29	**$t(9) = -2.77$, $p = .02$**
P5	4.21	$t(9) = 1.36$, $p = .20$
P6	1.94	$t(9) = .11$, $p = .91$

DISCUSSION

As discussed in the introduction of this chapter, the present study faced several practical limitations, which prevented the realization of the original plan comprising of two experiments, aiming to replicate and extend the studies reported in Chapter 3 and 4. Although the duration of the recruitment was quite long, the final sample consisted of only six patients with mild AD. Therefore, patients underwent only with the dual task experiment (Chapter 4) and the neuropsychological battery was used as a general cognitive assessment. Unfortunately, none of these patients showed CIB in either the shape copying or Luria's figure copying tasks. This group was not specifically suitable to replicate the single case results and to test between the hypotheses of CIB, not only because of the small size of the sample, but also for the absence of the phenomenon.

Although none of the patients showed CIB, the attraction hypothesis still predicts that patients with AD would show a higher line drawing bias toward the location of the letters than the control group. As assumed in the discussion of Chapter 4, the default tendency of migration toward the attentional focus is likely to appear with the increase in the difficulty of the visual task. The complexity of the task can derive from the task itself or from cognitive factors that render a patient less able to perform a given task. Therefore, the presence of a global deterioration, and the attention and executive deficits suggested by the neuropsychological battery, predict that the patient group would show a greater line drawing bias toward the attended letters than the control group. The results of the dual task experiment did not support this prediction. This null result could be related to the composition of the two groups. An important shortcoming of this study is that the control group recruited was not assessed for general cognitive status. Therefore, one possibility is that some of these participants might have presented impairment in one or more cognitive domains. On the other hand, the patients' group was composed of patients with mild AD. It is possible to speculate that the similar performance of patients and controls in the dual task experiment may be due to insufficiently dissimilar cognitive profiles. Moreover, in the analysis of patients' performance as independent single cases, the performance of each patient did not differ from the performance of the control group. Only one patient showed an abnormal performance compared to the controls, showing a line drawing bias away from the location of the letters. It is hard to draw firm conclusions from this result. Since the alpha level was not corrected for multiple comparisons; there is a high risk that the apparent impairment, which is mild, could have arisen by chance. Finally, the present study is constrained by the same limitations as the study reported in the previous chapter, in that, the study focus was on testing the attraction hypothesis of CIB and it did not test the compensation hypothesis directly. Therefore, no major conclusions against this last hypothesis can be drawn.

On the other hand, the results showed a significant interaction between the density and the position of the letters. A line drawing bias toward the letters appeared in the low density condition but not in the higher density condition. This result was confirmed by one sample t-tests, which found a trend toward a significant deviation of the line drawing condition in the low density but not in the high density condition. Therefore, a small manual attraction toward the focus of attention was elicited in patients and controls, but solely in the low density condition. This last evidence runs counter to the prediction of the attraction hypothesis, which posits an increase of manual bias with increased difficulty of the visual task. The manipulation of letter density was designed to increase the visual attention required by the dual task. One possible explanation of the appearance of a manual bias toward the focus of attention solely in the low density condition could be that the high density condition enhanced the monitoring of the manual performance. In the high density condition, the spatial distance between the letters was reduced. This smaller spacing between the letters might have encouraged more regular checking of the hand position, such as if the patient tended to check the hand as each letter was passed. One possible way to assess this idea might have been to examine possible differences between the time spent to perform the tasks and the eye movements in the high and low density conditions. If the high density condition induced greater manual monitoring, participants would have spent more time performing the line drawing than in the low density condition. The analysis of the possible difference in the eye movements between low and high density condition would have provided further information about the degree of visual monitoring. This hypothesis is speculative and future experiments will have to take into account this interpretation, monitoring the eye movements using eye tracker methodology.

Overall, the variation of the density of the stimuli proved not to be a powerful manipulation, at least for the intended purpose. In the single case study of the AD patient (see Chapter 4), the line drawing bias toward the letter's position was not influenced by the density of the stimuli. Similar results were also obtained with pre-school children (see Chapter 7), confirming the general weakness of this factor in modulating CIB.

To conclude, the results of the present study suggest that this dual task condition can elicit a manual bias toward the focus of attention in patients and normal adults, solely when the density of the visual stimuli is not particularly high. Moreover, these results suggest that the present dual task experiment is not only able to mimic CIB in graphic copying (see Chapter 4 and 7), but also to elicit this default behaviour in patients and normal controls.

The second section of this thesis will explore CIB in development, using similar methodologies similar to those applied in the present section. It will investigate the characteristics and cognitive bases of CIB in pre-school children, testing the possibility of a common cognitive nature of CIB in development and dementia.

SECTION 2

EXPLORING CLOSING-IN BEHAVIOUR IN DEVELOPMENT

CHAPTER 6
Closing-in Behaviour in preschool children

INTRODUCTION

In the previous chapters, the tendency, in copying tasks, to perform the copy abnormally close to or even on top of the original model, known as CIB, has been explored in patients with dementia. As illustrated in Chapter 2, this behaviour is not confined to pathology but is common in pre-school children. Using a simple graphic copying task, Gainotti (1972) estimated CIB frequency at 75% amongst 2-3 year-olds, 45% amongst 3-4 year-olds, 24% amongst 4-5 years old (24%), being rare after 5 years old (8%). CIB therefore, appears as a normal feature during development, but it can also arise in adults as a consequence of focal brain damage (Conson et al., 2009; Grossi et al., 1996; Septien et al., 1992; Vereecken, 1958) or various forms of dementia (Ambron, Allaria, McIntosh, & Della Sala, 2009a; Ambron et al., 2009c; Gainotti et al., 1992; Grossi et al., 1978). Although superficial similarities between the appearance of CIB in children and in patients with dementia have been noted (Gainotti, 1972; see also Chapter 2), it is unclear whether CIB in development and dementia reflect common underlying cognitive mechanisms.

As described in the previous chapters, two main hypotheses have been introduced to explain CIB: the compensation hypothesis and the attraction hypothesis. The compensation hypothesis proposes that CIB is a strategy adopted in copying tasks to compensate for visuo-perceptual or memory difficulties (Lee et al., 2004). In young children, immaturity of the visuo-perceptual system could impede the analysis of the model or its mental representation. Similarly, limitations of memory could prevent retention of a mental representation of the model, for the time required to produce a copy, even if the representation is well-constructed. In either case, the child might compensate by moving the working space toward the model, facilitating a more direct tracing strategy.

The attraction hypothesis, by contrast, interprets CIB as a default behaviour, whereby the hand performing the copy is attracted toward the focus of attention (the model). Several authors have hypothesised that this default attraction to the focus of attention may be released in patients with focal brain damage or dementia due to reduced attentional resources (Ambron et al, 2009c; Conson et al, 2009; McIntosh et al., 2008; see also Chapters 3 and 4). This account received some support from the cohort study with patients with AD described in Chapter 3. In this study, 797 protocols of patients with AD, who underwent a standardised cognitive battery (incorporating visuospatial, memory, and attentional subtests) were retrospectively reviewed. In this sample of patients, poor performance in the attentional subtest emerged as the best predictor of the near-type of CIB, while both attention and visuospatial abilities predicted the overlap-CIB. Moreover, some specific characteristics of CIB and CA in AD, already mentioned in the literature review (see Chapter 2), emerged from this study. First, CIB and CA were found to be more frequent with increasing severity of AD (De Ajuriaguerra et al., 1960; Gainotti, 1972; Ober et al., 1991). Second, the frequency of CIB and CA increased when patients were required to perform complex graphic copying tasks (Mayer Gross, 1935; Muncie, 1938; Grossi et al., 1978). If similar mechanisms underlie the developmental form of the phenomenon, then the characteristics of CIB in patients with AD and in pre-school children should be similar and attentional insufficiencies should predict CIB in pre-school children.

With a rationale similar to the study described in the previous section (see Chapter 3), the present study was set up to (i) explore the characteristic of CIB in preschool children (Experiment 1) and, (ii) to investigate the cognitive correlates of CIB in pre-school children (Experiment 2). The first experiment addressed the questions of whether or not the complexity of the graphic copying task and the age of the children have an effect on constructional skills and CIB in pre-school children. The second experiment investigated the cognitive nature of CIB, targeting visuospatial abilities, short term memory, and attention. The compensation hypothesis predicts that CIB will be preferentially related to poor performance on visuospatial and/or memory tasks. Alternatively, recent evidence suggests that attentional insufficiencies may be more closely related to CIB, which would be compatible with the attraction hypothesis (McIntosh et al., 2008). The present findings support the latter interpretation and the hypothesis that CIB in development and dementia not only presents similar characteristics, but also reflects common cognitive mechanisms.

MATERIAL AND METHODS

Participants

Forty-one (17 males and 24 females) pre-school children (3-5 year old) attending two nurseries were recruited for the study. Children were retrospectively divided, as evenly as possible, into three groups of increasing age: Group 1 (n = 14) had a median age of 44 months (range 36-49); Group 2 (n = 13) had a median age of 53 months (range 49-57); and Group 3 (n = 13) had a median age of 61 months (range 58-67). Demographic information was limited to age and sex. The handedness of the children was not recorded due to the difficulty in determining the direction of the handedness in children in this age range (McManus et al., 1988**.** The children completed two experiments, which took about 30 minutes overall and were spread across two to three test sessions, depending on the child's level of interest and willingness to participate. Most children completed Experiment 1 in the first session and Experiment 2 in the second session.

The children performed tasks for the assessment of CIB, constructional skills (CS), visuospatial abilities, working memory, and attention. These tests were performed over three sessions of ten minutes, across a maximum of three separate days, and were presented as games that the children were invited to play with the examiner.

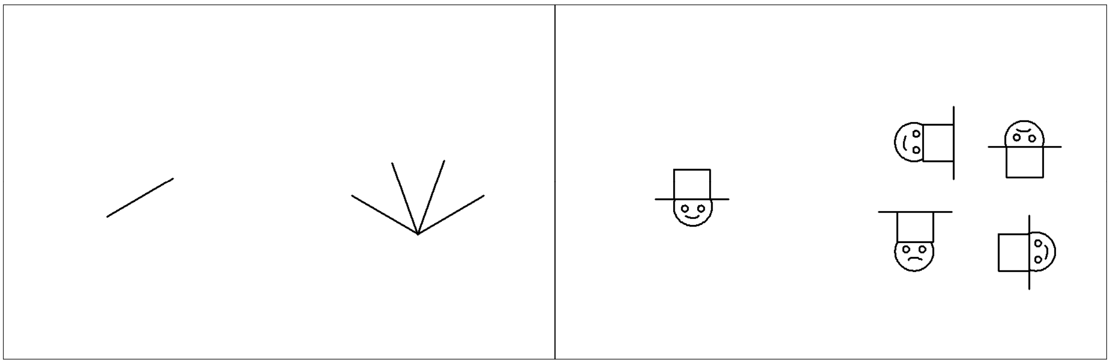
This study received ethical approval from the Ethics Committee of the School of Philosophy, Psychology, and Language Sciences, University of Edinburgh and the legal guardians of the children provided informed consent for the children's participation in the study.

Cognitive tests

Visuospatial Tasks

The assessment of visuospatial abilities was carried out using a modified version of the BVA (Angelini et al., 1993), previously used by Del Giudice et al. (2000) in children. The children were presented with visuo-perceptual and mental-representation task (see Appendix Chapter 6b for the complete task). In each task, the target was a black and white picture (roughly 40 × 40 mm) presented on the left side of an A4 paper in a landscape orientation. Four choices were presented on the right part of the same paper, one of which matched the target. The instruction was to point the item matching the target, and one point was scored for each correct answer**.** The visuo-perceptual task had sixteen trials: children were asked to recognize the lengths of lines (4 trials), the orientation of lines (4 trials), the position of points (4 trials) and simple geometrical shapes (an ellipse, a square, a rectangle, and a circle) (4 trials). The mental-representation task had twelve trials (maximum score = 12). Children were asked to recognise complex multipart shapes (4 trials), hidden geometrical shapes (4 trials), and stylised faces presented at different rotations (4 trials) (see Figure 6.1).

Figure 6.1. Left panel example of visuo-perceptual task. Right panel example of mental-representation task.



Working Memory Tasks

Phonological working memory was assessed with the Digit Span of the WAIS-R (Wechsler, 1981) and visuo-spatial working memory with a modified version of Corsi Block Tapping task (Corsi, 1972).

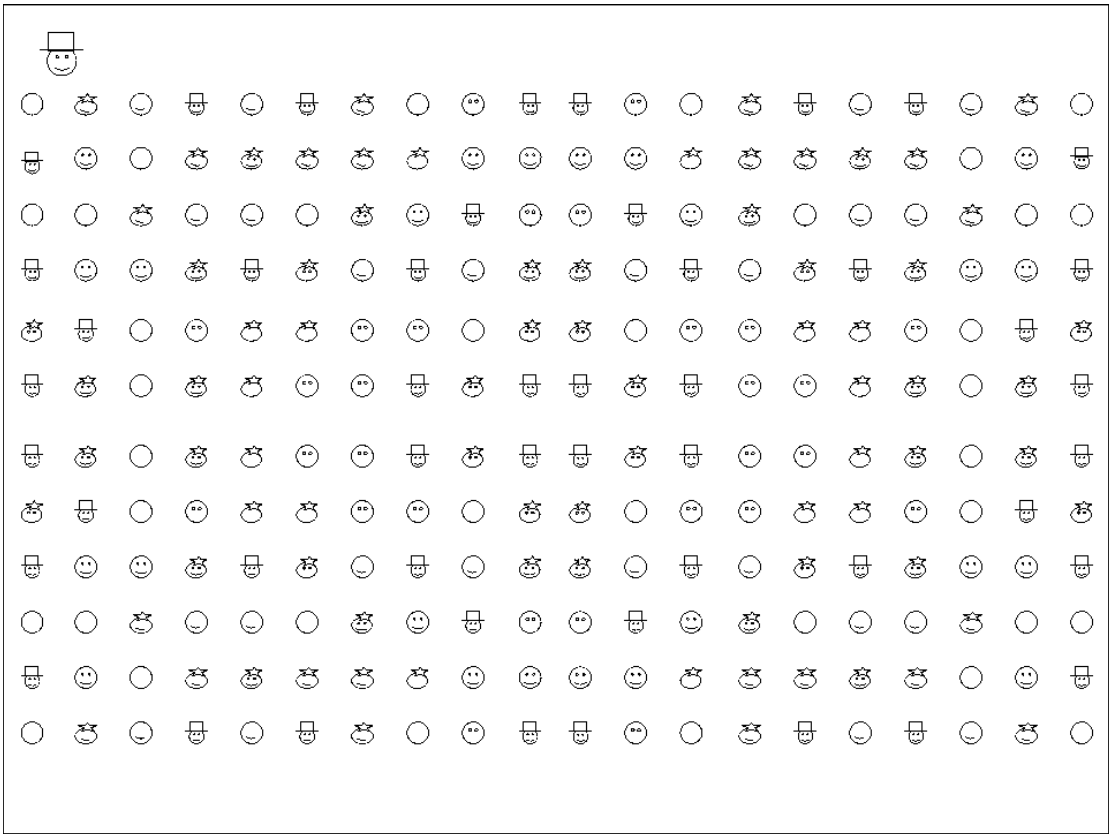
In the Digit Span, children were verbally presented with strings of digits and asked to repeat the digits in the same order forwards. Strings of the same number of digits were presented twice, beginning with two digits. If the child recalled either sequence correctly at a given string length, then the string length was increased by one for the next pair of trials, up to a maximum of seven digits. The task concluded when the child was unable to correctly repeat either of two strings of digits of the same length, or had completed both trials of the seven-digit strings. One point was given for each string of digits the child could recall correctly (maximum score 14).

In the Corsi Block test, the original spatial arrangement of the 9 blocks was maintained but the size of the blocks (50 × 50 mm) and of the board (470 × 365 mm) was increased in order to reduce the demands on motor accuracy for the children. Two procedures were used: the classical procedure and an *adding blocks procedure*. In the classical Corsi Block Tapping task, children were presented with nine blocks and were asked to repeat the sequence of blocks tapped by the examiner in the same order forwards. Sequences of same number of blocks were presented three times, beginning with two blocks. The children had maximum five chances to correctly reproduce series of blocks of the same length. If the child recalled three sequences correctly at a given number of blocks, then the sequence length was increased by one block for the next trials, up to a maximum of nine blocks. Corsi Block task was scored as the sequences length that the children could reproduce correctly at least three times out of five trials (maximum score 9). The *adding cube procedure* was presented before the classical Corsi Block Tapping task and was designed to reduce the complexity of the task and to get the children to become familiar with the task. The blocks were placed one at time, starting with two cubes. Children were asked to repeat two sequences of two blocks tapped by the examiner. If the children correctly repeated the two sequences, a new block was added to the board and the children were asked to repeat sequences of the increased length. As for the classical procedure, children were given five chances to correctly reproduce three sequences of the same length and the maximum score was nine.

Attentional Tasks

Attentional functions were assessed using three sub-tests adapted from the Test of Everyday Attention for Children (Manly et al., 2001) to make them more suitable for younger children. In the *selective attention* task (see Figure 6.2), children were presented with a matrix of 240 stimuli (48 targets interspersed amongst 192 distractors), of 7 × 7 mm each, printed on an A4 sheet of paper, placed in a landscape orientation. At the top left, a target icon (stylised face wearing a hat) was displayed and children were asked to search and tick as many of these targets as they could in two minutes. One point was scored for each target ticked in 2 minutes (maximum score 48).

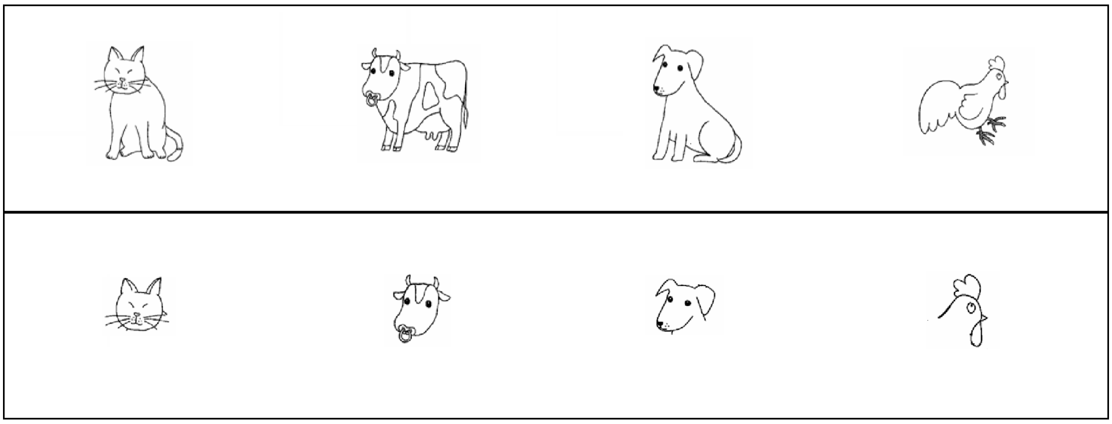
Figure 6.2. Selective attention task



In the *sustained attention* task, back and white drawings (approx. size: 58 × 75 mm) of animals (cat, dog, rooster and cow) (Figure 6.3), all known to the children, were presented in a fixed sequence on a computer screen (160 mm × 120 mm). Within the randomised sequence of 12 pictures, each of the four animal pictures was presented three times, for 2500 ms each time, intermingled with blank screens of variable duration (1500-7500 ms). The time duration of the blank screen was varied, and included relatively long intervals, in order to reduce the frequency and predictability of stimulus appearance, and thereby to emphasise the vigilance demands of the task (see Appendix Chapter 6c for the complete task). Children were required to name the animals as soon as they appeared on the screen, keeping their attention on the screen during the blank displays. A practice trial was given to the children in order to assess their ability to recognize and name the animals. All the children were able to recognize and name the animals correctly. One point was scored for each animal named (maximum score = 12).

In the *attention switching* task, children were presented with the animals used in the previous task, but now intermingled with drawings of the same animals' heads alone (Figure 6.3). Each of these eight stimuli (the four animals, and each of their heads alone) was presented twice within a random sequence, for 4000 ms each time, with no inter-stimulus interval (Appendix Chapter 6c for the complete task). The children were instructed to name the animals when the entire animal was shown, but to clap their hands when only the head was shown. The task thus required the children to switch between responses depending upon the stimuli presented. One point was scored for each correct response (maximum score = 16).

Figure 6.3 Top row, stimuli of the sustained attention and attention switching task; bottom row, stimuli of attention switching task.



For each test, the score was expressed as a percentage of the maximum possible score. Visuospatial abilities, working memory, and attention scores were calculated as the average across subtests within each category.

Experiment 1

This experiment aimed to assess the effect of figure complexity and the age of the children on CS and CIB, by assessing the graphic copying of nine geometrical shapes across three levels of complexity (simple, medium, complex) (see Appendix Chapter 6a for the complete task). The simple stimuli were a square, a triangle, and a circle; the medium-complexity stimuli were overlapped pairs of squares, ellipses, and triangles; the complex stimuli depicted the three-dimensional figures of a cube, a cylinder, and a pyramid. Each stimulus was 40 × 40 mm in extent and presented in the centre of the left half of an A4 sheet, in landscape orientation. Children were asked to copy each figure, without specific instructions regarding positioning of the copy, and with no time constraints. The pictures were presented in the following order: circle, overlapped ellipses, cylinder, square, overlapped squares, cube, triangle, overlapped triangles, and pyramid. Prior to beginning the task, the examiner performed one copy as an example and the children were required to repeat the instructions correctly in order to be sure that they fully understood the task.

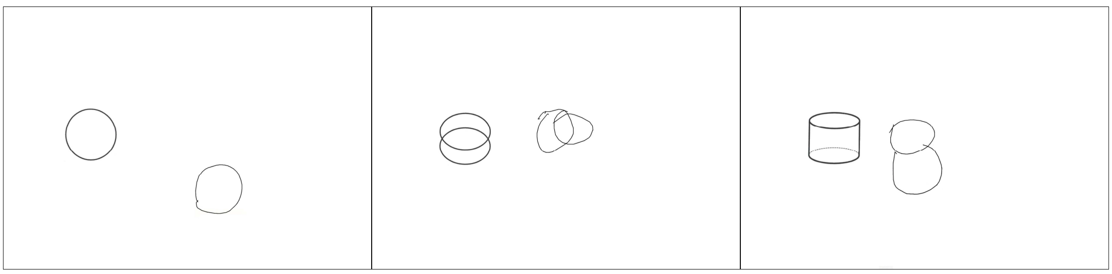
For each picture, CS were rated using a scale from 0 to 2, according to the following descriptors (see Figure 6.4 for examples):

0: Poor CS. The copy is unrecognisable.

1: Moderate CS. The copy is not accurate, but the model is partially recognizable.

2: Good CS. The copy is well executed, with no gross distortions of scale.

Figure 6.4. From the left panel example of Good, Moderate and Poor CS



CIB was similarly rated on a 0-2 scale, according to the following descriptors

0: Overlap-type CIB. The copy touches the edge of model in one or more points, or partially or wholly overlaps the model.

1: Near- type of CIB. The copy is performed very close to the model (< 10 mm shortest distance[11]).

2: No CIB. The copy is well-separated from the model (> 10 mm shortest distance).

Experiment 2

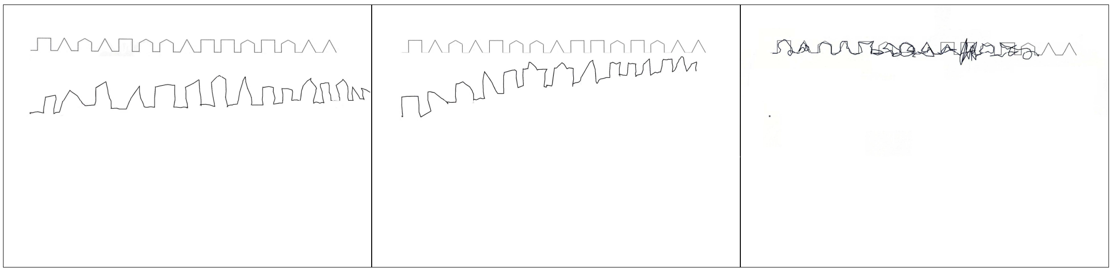
This experiment aimed to assess the cognitive bases of CIB in pre-school children, using the cognitive tests previously described and a more specific task for the assessment of CIB.

CIB assessment

CIB was assessed with a figure adapted from Luria (1966). This consisted of five square, five triangular, and five pentagonal elements distributed in a pseudo-random sequence along a horizontal line. Each element was 10 mm long and 10 mm high, and the connecting line between elements was 5 mm long. The figure was printed 30 mm from the top edge of an A4 paper in landscape orientation. A 4 mm diameter black dot was printed 50 mm below the model, and 25 mm from the left edge of the sheet. Children were required to start the copy with the pen on this black dot. No specific instructions about the required orientation of the copy were given, but the examiner indicated the ideal copying space, moving her hand in a horizontal line from the black dot point to the right edge of the paper. In addition, a demonstration of the copying task was given in some cases to make sure the children fully understood the task. CIB was classified as present when one or more units of the copy were drawn within 10 mm of model (Near CIB), or when the copy partially or wholly overlapped the model (Overlap CIB) (see Figure 6.5 for examples).

[11] As stated in the previous section, the operational definition of the near-type CIB as within 10 mm is arbitrary but aims to provide a more objective criterion.

Figure 6.5. Examples of the Luria's figure copying task, showing performance without CIB (left), and two examples of near and overlap CIB (middle and right).



RESULTS

Experiment 1

In the nine geometrical pictures copying task, poor and moderate CS appeared in 171 (46%) and 128 (35%) from a total of 369 drawings, while good CS were found only in 70 (19%) drawings. As expected, children's performance became less accurate copying more complex shapes and the percentages of drawing correctly reproduced decreased progressively with the complexity of the figure (Figure 6.6). Therefore, the percentage of drawings characterized as poor CS gradually increased and the percentages of drawings with moderate accuracy progressively decreased in copying complex shapes. A Friedman test confirmed the increase of CS frequency (moderate and poor CS considered together) between simple, medium, and complex copying tasks, $\chi^2(2) = 30.35$, $p < .001$. All post hoc comparisons showed a reliable difference in CS frequency between figure copying tasks[12]. Friedman test on the percentages of moderate, and poor CS considered independently showed a significant effect of the figure type on both moderate, $\chi^2(2) = 10.12$, $p = .006$, and poor CS, $\chi^2(2) = 47.20$, $p < .001$. All post hoc comparisons showed a reliable difference in poor CS frequency between figure copying tasks[13]. Instead moderate CS showed a lower frequency in the complex figure copying task compared to the simple, $z = -3.25$, $p = .001$, and moderate, $z = -2.43$, $p = .015$, figure copying tasks, but no

[12] Simple against medium complexity copying task, $z = -2.89$, $p = .004$; medium against complex copying task, $z = -3.38$, $p = .001$; simple against complex copying task, $z = -4.34$, $p < .001$.

[13] Simple against medium complexity copying task, $z = -2.56$, $p = .01$; medium against complex copying task, $z = -4.53$, $p < .001$; simple against complex copying task $z = -5.04$, $p < .001$.

significant difference appeared between simple and moderate figure copying tasks, $z = -0.73$, $p = .46$.

CIB occurred in 113 (31%) drawings, with the overlap-type more common than the near CIB (i.e. 19% vs. 12%). Figure 6.6 shows the percentage of drawings classified as overlap, near and no CIB for the simple, medium, and complex copying tasks. The percentages of CIB increased in complex shapes copying tasks. However, while the percentages of drawings with overlap CIB clearly increased for more complex shapes, near CIB appeared in similar percentages at the three levels of complexity. This evidence was confirmed by a Friedman test, which showed a reliable increase of CIB frequency (near and overlap considered together) between simple, medium, and complex figures, $\chi^2(2) = 8.61$, $p = .013$. Post hoc comparisons showed a significant difference in CIB frequency between simple and complex, $z = -2.58$, $p = .01$, and between medium and complex, $z = -2.08$, $p = .037$. No reliable difference was found between simple and medium complexity, $z = -0.88$, $p = .37$. In relation to the specific CIB typologies, the frequency of the near- type was similar at the three level of complexity, $\chi^2(2) = 4.42$, $p = .11$, while the frequency of the overlap CIB significantly varied among the figures, $\chi^2(2) = 6.29$, p = .043. However post hoc tests, with an uncorrected alpha level, showed that the only significant difference in the frequency of this type of CIB was between simple and complex figures, z = -2.13, p = .033[14].

[14] Simple against medium complexity copying task, $z = -.26$, $p = .79$; medium against complex copying task, $z = -1.94$, $p = .052$;

Figure 6.6. Percentages of drawings in each category of CS (diagram on the left) and CIB (diagram on the right) by figure type.

The black bar represents poor CS or Overlap CIB, the grey bar moderate CS or Near CIB, and the white bar good CS or no CIB.

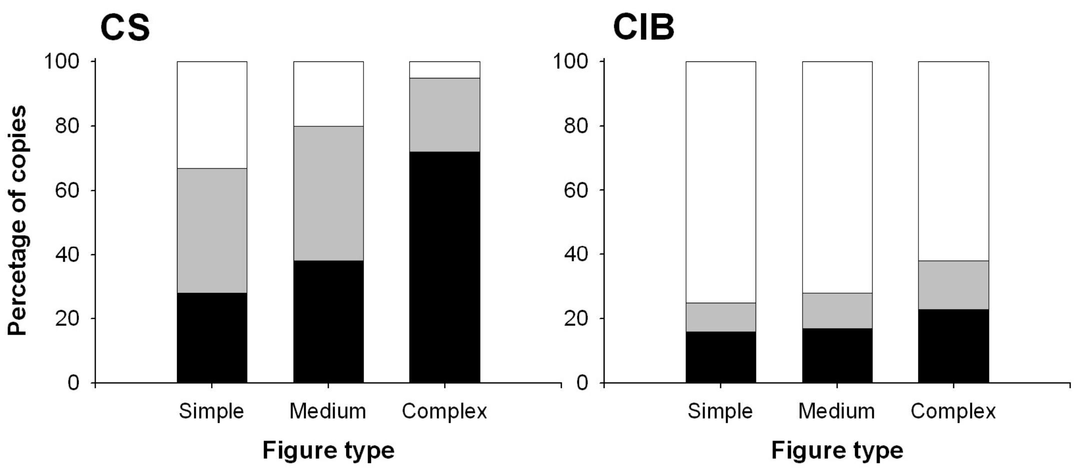
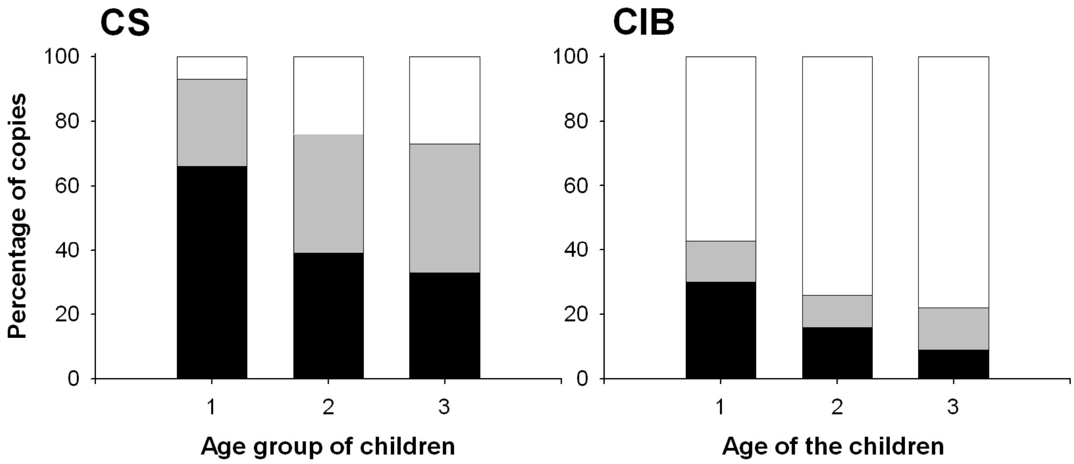


Figure 6.7 shows the percentages of drawings classified as moderate, and poor CS (diagram on the left), and as near and overlap CIB (diagram on the right) by age group of children. Both CS and CIB showed a parallel decrease with the age of the children. The frequency of moderate and poor CS considered together, $\chi^2(2)$ = 9.78, *p* = .008, reliably increased among the different age groups of children. Youngest children showed a higher frequency of moderate and poor CS considered together than children of Group 2, *z* = -2.69, *p* = .009, and Group 3, *z* = -2.71, *p* = .007, while no significant difference appeared between children of Group 2 and 3, *z* = -0.45; *p* = .68. Looking at poor and moderate CS independently, a Kruskal-Wallis test did not show a significant change in frequency for moderate CS, $\chi^2(2)$ = 2.90, *p* = .23, while poor CS reliably varied across the groups of children, $\chi^2(2)$ = 10.84, *p* = .004,: youngest children showed a higher frequency of poor CS than children of Group 2, *z* = -2.90, *p* = .004, and Group 3, *z* = -2.72, *p* = .006, while no significant difference appeared between children of Groups 2 and 3, *z* = -.66, *p* = .50.

Different results were found for CIB. A trend towards significance was observed for the overall CIB frequency (near and overlap CIB considered together), $\chi^2(2)$ = 2.13, *p* = .34, and for the overlap CIB, $\chi^2(2)$ = 2.89, *p* = .23, while the effect of age was far from significance for near CIB, $\chi^2(2)$ = .46, *p* = .79. These results suggest that this task is not particularly sensitive eliciting the variation of CIB with age (see Experiment 2 for a more specific CIB task).

Figure 6.7. Percentages of drawings in each category of CS (diagram on the left) and CIB (diagram on the right) by age of the children.

The black bar represents poor CS or Overlap CIB, the grey bar moderate CS or Near CIB, and the white bar good CS or no CIB.

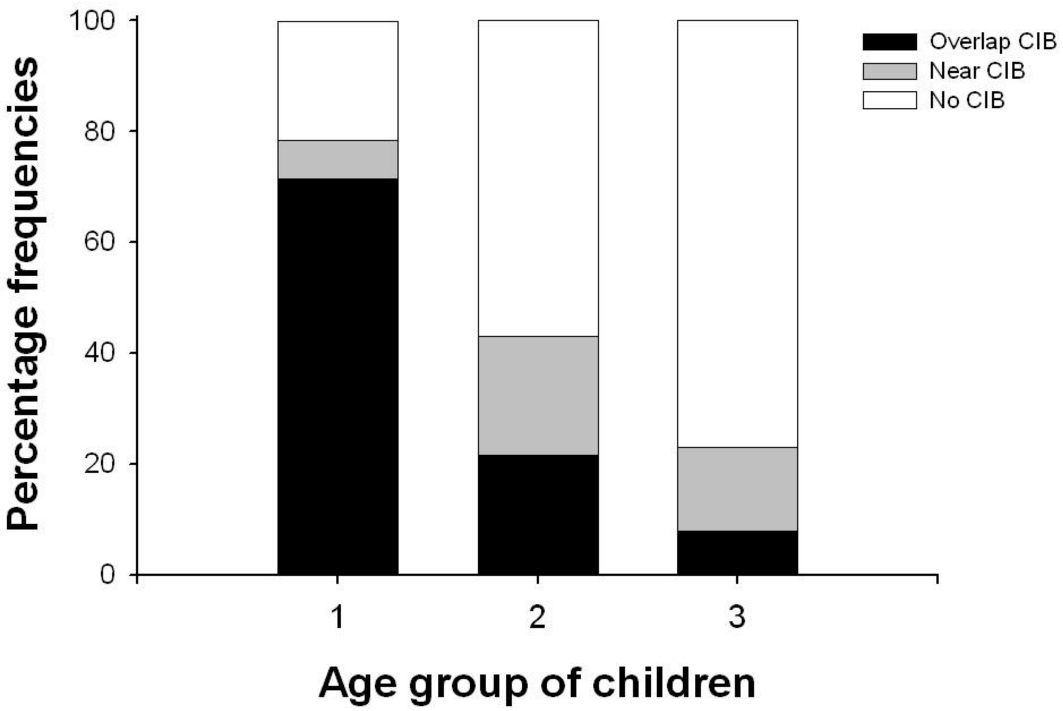


Experiment 2

In Luria's copying task, twenty (49%) from the total of 41 children showed CIB, with the overlap-type more common than the near (34% vs. 15%). CIB frequency (near and overlap considered together) decreased with the age of the children (Figure 6.8). A Kruskal-Wallis test confirmed a reliable effect of age on CIB in Luria's copying task, $\chi^2(2) = 11.74$, $p = .003$. Post hoc tests confirmed a significant difference in the frequency of CIB between Groups 1 and 2, $z = -2.43$, $p = .015$, and between Groups 1 and 3, $z = -3.21$, $p = .003$. However no significant difference appeared between Groups 2 and 3 in the overall frequency of CIB, $z = -1.13$, $p = .25$. In relation to the specific CIB typologies, the frequency of the near type was found not to differ reliably between groups, $\chi^2(2) = 1.12$; $p = .57$, while the overlap CIB frequency was significantly different among the three groups, $\chi^2(2) = 13.37$, $p < .001$. The frequency of this last type of CIB was higher in Group 1 compared against Group 2, $\chi^2(2) = -2.60$, $p = .024$, and Group 3, $\chi^2(2) = -3.30$, $p = .004$, but no significant difference was found between Groups 2 and 3, $\chi^2(2) = -0.98$, p= .55. The significant effect of age on CIB, which was found in Luria's copying task but not in the nine shape copying task of Experiment 1, suggests that Luria's copying task is a more sensitive measure of CIB in pre-school children.

As described in the Methods section of the present chapter, the raw scores for each task were transformed into percentages of correct answer and the median performance and range are reported in the Appendix Chapter 6d. The *adding blocks procedure* of the Corsi Block test showed an outcome similar to the classical Corsi Block test. Therefore it was considered as a practice trial and was not included in the analysis. The assumption of normality was violated for all the variables, except the overall visuospatial score and the Selective attention task (see Appendix Chapter 6d), so the analysis was carried out using non parametric tests.

Figure 6.8. Percentage frequencies in Luria's copying task for each of CIB by age of the children.



Across all groups, male and female children showed a similar performance in all cognitive subtests, $z < -1.7$, $p > .12$ (see Appendix Chapter 6e). As expected, children's performance in the different tasks increased progressively across groups of increasing age (see Table 6.1). A Kruskal-Wallis test found a significant difference in the performance of the three age groups of children in all the subtests, except the visuo-perceptual task[15]. Post hoc tests (see Apendix 4f) showed a better performance of children in the second group than Group 1 in all the tasks, except Corsi Block test and Sustained attention. Performance of Group 3 was reliably higher than Group 2 only in the Corsi Block test, but higher than children of Group 1 in all of the cognitive tasks.

[15] Visuo-perceptual, $\chi^2(2) = 5.65$, $p = .059$; Mental Representation, $\chi^2(2) = 11.98$, $p = .003$; **Visuospatial,** $\chi^2(2) = 12.78$, $p = .002$; Digit Span, $\chi^2(2) = 8.20$, $p = .017$; Corsi Block test, $\chi^2(2) = 14.33$, $p = .001$; **Working Memory,** $\chi^2(2) = 12.54$, $p = .002$; Selective attention, $\chi^2(2) = 23.60$, $p < .001$, Sustained attention, $\chi^2(2) = 9.14$, $p = .01$; Attention switching, $\chi^2(2) = 6.87$, $p = .032$; **Attention**, $\chi^2(2) = 23.44$; $p < .001$.

Table 6.1. Median performances and Range in the different subtests for each age group of the children.

		Group 1 (44 months)	Group 2 (53 months)	Group 3 (61 months)
Visuo-percetual	Median Range	62 50-88	72 50-88	75 44-94
Mental representation	Median Range	33 8-75	50 25-58	50 42-92
Visuospatial	Median Range	56 32-65	61 41-72	62 47-86
Digit Span	Median Range	14 0-43	29 7-43	21 14-43
Corsi Block test	Median Range	22 0-44	33 0-44	44 22-44
Working Memory	Median Range	18 0-35	32 4-38	33 22-44
Selective attention	Median Range	21 6-65	64 29-96	71 52-94
Sustained attention	Median Range	79 25-100	96 58-100	100 83-100
Attention switching	Median Range	50 12-94	84 37-100	87 37-100
Attention	Median Range	53 17-68	81 53-94	83 67-96

The effect of the age of the children on CIB and on the performance of the different cognitive tasks was confirmed by Spearman's Rho analysis (see Appendix Chapter 6f). All the cognitive subtests were significantly correlated with CIB (visuospatial *rho* = .36, p = .016; working memory *rho* = .44, p = .003; attention *rho* = .66, p < .001), as would be expected given the demonstrated influence of chronological age on all cognitive subtests. In order to explore the specific cognitive predictors of CIB, a binary logistic regression was performed with CIB presence (near and overlap considered together) as the binary dependent variable, and age in months, visuospatial, working memory and attention scores entered as predictors**.** The visuospatial score inserted in this analysis was the average score of Visuo-Perceptual and Mental Representation Tasks, and the mean CS score of the nine pictures copying task of Experiment 1. Prior to running the regression analysis, multicollinearity effect was checked and none of the correlation coefficients was higher than 0.72 (see Appendix Chapetr 6g). Binary logistic regression found that the model with all the predictors inserted was statistically significant, Model $\chi^2(4)$ = 27.71, p < .001; Cox & Snell R^2 = .491. As shown in Table 6.2a, the best unique predictor of CIB was the Attention score, suggesting that the symptom is more closely related to attentional, than to visuospatial or memory abilities. To further explore whether CIB was differentially related to the three attention subtasks, a second binary logistic regression was performed, with age in months, selective attention (median score 58%), sustained attention (median score 92%) and attention switching (median score 69%) scores as predictors. The test of the full model against a constant only model was significant, Model $\chi^2(4)$ = 27.21, p < .001, Cox & Snell R^2 = .485, and in this analysis, the attention switching task emerged as the only significant unique predictor of CIB (see Table 6.2 b).

Table 6.2. Binary logistic regression

		B	**Wald**	*p*	*Exp (B)*
a)	*Constant*	6.82	5.69	.01	915.92
	Age (in months)	-0.29	.174	.67	.971
	Visuospatial	.034	.299	.58	1.035
	Working memory	.050	1.069	.30	1.051
	Attention	-.113	5.093	.024*	.893
b)	*Constant*	6.307	4.33	.037	548.48
	Age (in months)	-.056	.0522	.47	.946
	Selective attention	-.014	.393	.53	.986
	Sustained attention	-0.001	.000	.98	.999
	Attention switching	-0.040	5.891	.015*	.946

* *p* uncorrected for the additional analysis[16]

[16] The *p* value was not corrected for multiple comparisons, due to relatively low power. However, as shown in Table 2 both results would have survived Bonferroni correction.

DISCUSSION

Experiment 1 assessed the effect of the complexity of the graphic copying task on CS and CIB. The results showed that the performance of the children was more accurate when copying simple bidimensional geometrical shapes rather than more complex overlapped bidimensional or three-dimensional shapes. In a similar way the frequency of CIB progressively increased when copying more complex shapes. Another important result of Experiment 1 is that the age of the children influenced the frequency of CS. The ability to reproduce the nine geometrical shapes increased with general cognitive development and the reproduction of the shape was more accurate in older children. On the contrary, the age of the children did not have a significant impact on the frequency of CIB in the nine shapes copying task. This result was surprising since previous reports (Gainotti, 1972) showed that CIB is a common behaviour in pre-school children, which decreases in frequency as children grow older. The present lack of effect suggests that these graphic copying tasks were not specifically able to detect the variation in CIB frequency between age groups of children. On the contrary, a significant effect of the age appeared in Experiment 2 when Luria's figure was used to specifically assess CIB. Therefore, this result confirmed that Luria's figure is more sensitive to CIB, presumabily because its laterally extensive characteristic allows the development of CIB during the copying time (see Chapter 4) and might be therefore particularly effective in eliciting CIB in children (see also Chapter 7).

Experiment 2 goes beyond prior reports by investigating the cognitive factors associated with the phenomenon. This test battery targeted three main classes of ability – visuospatial, working memory, and attentional – as motivated by the dominant accounts of CIB within the literature (see Introduction). Regression analysis, which took chronological age into account, found that the attentional score was the only significant unique predictor of CIB. This result suggests that immaturity of visuospatial and memory functions cannot be held responsible for the appearance of CIB, contrary to the compensation hypothesis (Lee et al., 2004). The pattern instead supports the attraction hypothesis, according to which attentional difficulties are the crucial cognitive factors underlying CIB (Ambron et al, 2009c; Conson et al, 2009; McIntosh et al., 2008).

A second regression analysis, focusing on the specific attentional subtests, indicated that, within the attentional battery, the attention switching subtest was the single unique predictor of CIB. This task required children to switch between two responses (verbal or motor) depending upon the stimulus presented (whole animal or head only). It is tempting to relate the predictive power of this subtest to demands for attention switching that may be inherent to copying tasks. In order to succeed in graphic copying, the child must maintain different response rules for the model, which must be visually attended but not acted upon, and the copy, which must be attended to *and* acted upon. Successful copying, therefore, requires not only the switching of spatial attention between copy and model, but also a switching between analysis and production. A failure to keep these two task components separate could cause them to merge together, with the hand tending to follow the eye toward the model. This specific association of CIB with attention switching, and the interpretation suggested for it, are speculative, requiring further investigation. However, the main outcome of a preferential association of CIB with attentional insufficiency, seems relatively clear.

A possible alternative explanation for this outcome would arise if the attentional tasks (and the switching task in particular) were somehow more difficult than the visuospatial or working memory tasks, and thus more sensitive to overall cognitive capacity. If this were the case, then a non-specific sensitivity to cognitive immaturity might underlie the apparent relation between attention and CIB. However, several aspects of the data argue against any such relationship. First, visuospatial, working memory and attentional scores all correlated highly with age in months ($p < 0.0005$), indicating that all were highly sensitive to cognitive development. Moreover, there were no compression effects apparent for any of the visuospatial or working memory subtests, indicating that they effectively measured the full range of ability in the sample. In fact, attentional subtests were more prone to compression effects, with 12% of children performing at ceiling in the attention switching task, and 46% of children at ceiling in the sustained attention task. (The latter was the only severe compression effect amongst the subtests, suggesting that the present analysis may potentially underestimate the relation between CIB and sustained attention). These patterns provide reassurance that the relationships observed are real and relatively specific to attentional abilities. Finally, one limitation of the present study is that Luria’s figure was presented at the top of the paper only, leaving open the possibility that a tendency to drift up the page during drawing could have been mistaken for CIB in some children. In order to distinguish between motor drift and truly model-directed migration, the position of the model should have been varied, as it was done in other studie of the present thesis (See Chapter 4, 5, and 7). However, it should be noted that the majority of cases of CIB (14/20) in the present sample involved overlap of the copy on the model, which would be difficult to explain as simple motor drift.

Consistent evidence supporting the relationship between CIB and attention has also been obtained in the large cohort study with patients with AD described in Chapter 3 (Ambron et al., 2009c). In this group of patients, performance in the attentional subtest emerged as the best predictor of CIB. Moreover, in this large cohort of patients with AD, significant effect of the complexity of the task and of the severity of dementia on CA and CIB were observed. As in the present study, CIB and constructional difficulties were more frequently observed in copying more complex figures (see results of Experiment 1). On the other hand, the frequency of CA and CIB progressively increased with the severity of dementia. Although direct comparison between these studies is not possible since different model shapes from the present were used, superficial similarities can be noted. In both groups, the frequency of CIB and the poor accuracy of the reproduction progressively increased in more complex graphic copying tasks. Moreover, the frequency of CIB showed a mirror pattern in the two groups: while CIB decreased with the age of the children, the frequency phenomenon progressively increased in severe dementia. This evidence replicates previous observations (Gainotti, 1972) and supports the speculative hypothesis that CIB is a primitive default behaviour, common in young children, which progressively disappears with age and then reappears in the course of dementia.

One important limitation of the present study in exploring the cognitive origins of CIB is that the phenomenon was classified as present or absent and the different types of CIB were not distinguished in the regression analysis. Therefore, the present results must be considered as indicative and the role of the immaturity of visuospatial and working memory function in the appearence of the specific types of CIB cannot be definitively excluded.

To summarize, this study shows initial support for the attraction hypothesis of CIB. The role of attention in the appearance of CIB and the superficial similarities noticed in the present sample of pre-school children and in patients with AD (Chapter 3) suggest that the phenomenon may have a similar cognitive nature in development and dementia.

In the studies described in the present chapter, the two competing hypothesis of CIB in children were explored indirectly, assessing the relationship between CIB and visuospatial abilities, memory, and attention. However, the approach so far has been merely correlational. The following Chapter is therefore dedicated to experimentally testing between the compensation and attraction hypothesis of CIB in pre-school children.

CHAPTER 7
An experimental study of closing-in behaviour in pre-school children

INTRODUCTION

As described in the previous chapter (see also Chapter 2), when young (pre-school) children are asked to copy drawings, a significant proportion will construct their copy excessively close to, or even on top of the original model, as if drawn magnetically to that which already exists on the page (Prudhommeau, 1947; Wallon and Lurçat, 1957). This normal aspect of graphic development closely resembles the pathological phenomenon seen in adult neurology, termed ‘closing-in behaviour’ (Mayer-Gross, 1935), classed as a form of CA (e.g. Critchley, 1953; Grossi & Trojano, 2001). The relatively small, but surprisingly diverse literature on CIB indicates that attraction toward a model can emerge across a variety of copying tasks (e.g. drawing, writing, 3D construction, gesture imitation) and with wide-ranging aetiologies (dementia, cerebral stroke, carbon monoxide poisoning, corticobasal degeneration, encephalitis, epilepsy) (Crichley, 1953; De Ajuriaguerra et al., 1949; De Renzi, 1959; Denny-Brown, 1958; Kwon et al., 2002; Lhermitte and Mouzon, 1941; Mayer-Gross, 1935; Muncie, 1938; Stengel et al., 1944; Vereecken, 1958).

As described in previous chapters, two classes of hypotheses have been proposed to account for CIB in brain-damaged adults. Some authors have suggested that CIB arises as a strategic attempt to compensate for insufficient visuospatial or working memory resources (e.g. Muncie, 1938; Lee et al., 2004). The compensation hypothesis suggests that the distance between the copy and the model is reduced in order to lighten the visuospatial and/or working memory load imposed by the task. An alternative suggestion is that CIB is a primitive, default behaviour in which the acting hand is drawn toward the focus of visual attention (the model) (De Ajuriaguerra et al., 1960; Gainotti, 1972; Kwon et al., 2002). The details of this account will be considered in later discussion, but the basic proposal is crucially distinct from that of the compensation hypothesis. According to the compensation hypothesis, CIB is a functionally adaptive strategy to aid copying performance; according to the attraction hypothesis, CIB is non-functional, arising merely from the failure to inhibit a default attraction toward the focus of visual attention**.** This account received some support in the single case study of a patient with AD (Chapter 4; see also McIntosh et al., 2008). This patient was asked to draw a horizontal line across a sheet of paper and simultaneously to identify letters at the top or the bottom of the sheet. Under these dual-task conditions, a marked manual migration toward the focus of attention (location of the letters) emerged. The elicitation of CIB by this dual-task implies that, although this behaviour usually arises in copying tasks, it is not specifically related to the copying requirement, but rather to the more general tendency to act toward a location removed from the focus of attention.

In the present study, a similar experiment to the one used with the single case study was designed to test between these two hypotheses in a group of 15 pre-school children, using a straight line drawing task in conjunction with a visual animal naming task. The compensation hypothesis predicts that CIB should be specific to situations, such as copying, in which manual performance could benefit from information available elsewhere. By contrast, the attraction hypothesis predicts that manual performance in pre-school children should tend to migrate toward any sufficiently attention-demanding visual stimulus, regardless of its relevance to the manual task. The present data demonstrates that drawing in children is attracted toward the focus of attention defined by an *unrelated* visual discrimination. This result shows that CIB in children is not specific to copying tasks, and provides clear evidence for favouring the attraction hypothesis over compensation accounts. In discussing these findings, the cognitive factors that might underlie the release of a primitive manual attraction toward the focus of visual attention, and the relationship between CIB in development and dementia will be considered.

MATERIAL AND METHODS

Sample

Fifteen children (ten females and five males) were tested at a day nursery. The age range of the sample was 4.0-5.8 years old (mean age 4.2 years, *SD* = .41). The children were tested in the presence of nursery staff. The tests were presented as a ‘game’ and the children were invited to play with the examiner. In total, testing took about 30 minutes per child. This study received ethical approval from the Ethics

Committee of the School of Philosophy, Psychology and Language Sciences, University of Edinburgh. The agreement of the legal representatives of the children was obtained before children were invited to participate.

Preliminary graphic copying tasks

As part of a concurrent study, all of the children performed some preliminary graphic copying tasks. These tasks were used to characterise graphic copying abilities in the present sample, though the data are drawn from a larger dataset (see Chapter 6).

The children were asked to copy nine geometrical pictures, varying in complexity (simple, medium, complex). The simple stimuli were a square, a triangle, and a circle; the medium-complexity stimuli were overlapped pairs of geometrical figures (overlapped squares, ellipses, and triangles); the complex stimuli depicted three-dimensional figures (cube, cylinder, and pyramid). Each stimulus was 40 × 40 mm in extent and presented in the centre of the left half of an A4 sheet, in landscape orientation. Children were asked to copy each figure, without specific instructions regarding positioning of the copy, and with no time constraints.

For each picture, constructional skills (CS) were rated on a scale from 0 to 2, according to the following descriptors:

0: Poor CS. The copy is unrecognisable.

1: Moderate CS. The copy is not accurate, but at least some parts of it are recognizable.

2: Good CS. The copy is well executed, with no gross distortions of scale.

Additionally, CIB was rated on a 0-4 scale[17], according to the following descriptors:

0: The copy wholly overlaps the model.
1: The copy partially overlaps the model.
2: The copy touches the edge of model in one or more points.
3: The copy encroaches on the model (< 10 mm shortest distance).
4: The copy is well-separated from the model (> 10 mm shortest distance).

In order to further assess CIB, each child was asked to copy a figure adapted from Luria (1966), consisting of five square, five triangular and five pentagonal elements in rotating sequence along a straight line (see Figure 7.1). Similar stimuli have been used for the assessment of CIB in patients with AD (Lee et al., 2003; McIntosh et al., 2008). Each element was 10 mm long and 10 mm high, and the line connecting the elements was 5 mm long. A sheet of A4 paper in landscape orientation was presented with Luria's figure along the top of the sheet, 30 mm from the top edge, and a 4 mm diameter black dot centred vertically (50 mm below the model) 25 mm from the left edge of the page. The instruction was to copy the picture, starting with the pen on the black dot. The previously stated descriptors for copy quality and CIB were used to rate each child's performance on this copying task.

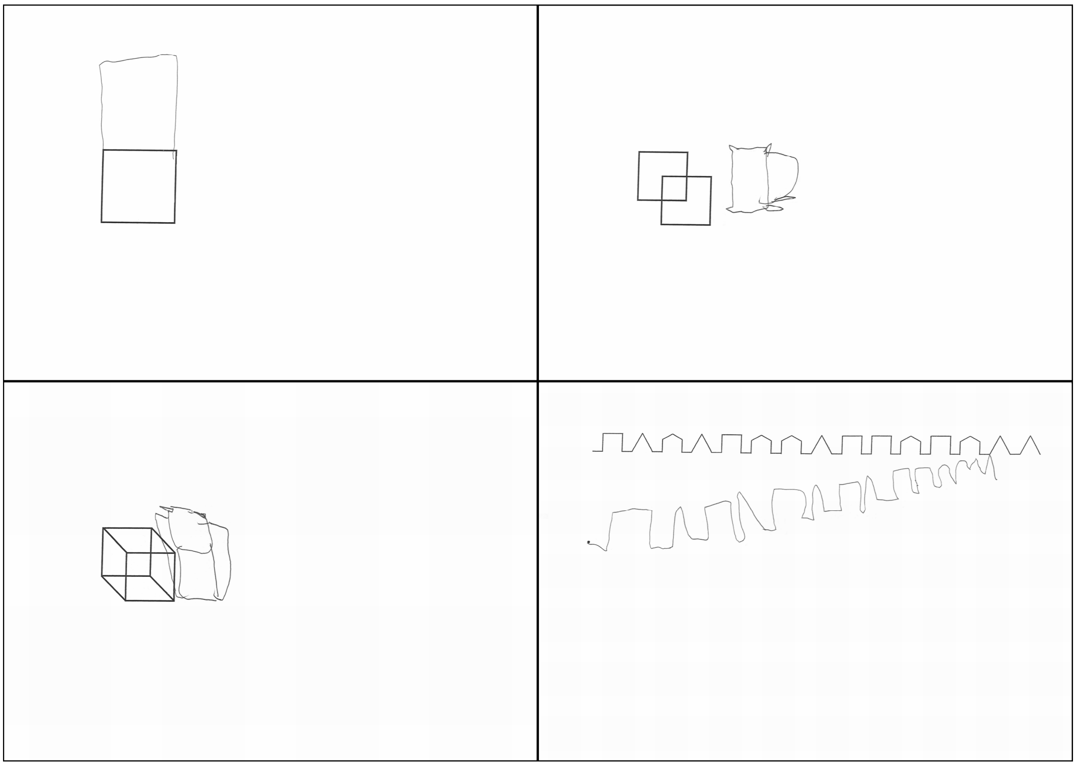
To assess the reliability of the above scales, all 150 drawings were scored independently by two raters. Identical CS scores were awarded on 111 trials (74%), and the magnitude of the inter-assessor discrepancy never exceeded one point (Assessor 1 awarded the higher score for 19 drawings, and Assessor 2 awarded the higher score for 20 drawings). The inter-assessor correspondence was even more close for the CIB scale, with identical scores awarded on 136 trials (91%); again, the

[17] The data analysis of this study was conducted chronologically before the study reported in the previous chapter. This scoring procedure was modified in the study reported in the previous chapter, as it was considered more useful to assess the appearance of CIB in relation to the age of the children and for consistency with the studies conducted with patients with dementia. The present categorization is more detailed and useful to describe the appearance of CIB in small samples, but it may not be so suitable to assess the phenomenon in a larger group. In the scoring procedure used in Chapter 6, scores from 0-2 were labelled under the unique category of Overlap CIB, since it was afterwards reasoned that all these categories describe a unique behaviour which comprises an invasion of the the model space in graphic copying.

magnitude of the inter-assessor discrepancy never exceeded one point (the two assessor awarded the higher score for seven drawings each). For each drawing, for each scale, the final score awarded was the average of the two assessors' scores. For each child, an average score was then calculated across the three figures at each level of complexity (simple, medium, complex) for each scale.

Figure 7.1. Examples of CIB for simple (upper left), medium (upper right) and complex (lower left) geometric figures; and for Luria's figure (lower right).

These examples illustrate CIB scores of 2 (contact, upper left), 3 (encroachment, upper right), and 1 (partial overlap, lower left). The pattern of migration toward Luria's figure from the starting point is typical of CIB in this task. No examples of CIB scoring zero (complete overlap) were observed in any child. Note that CIB can be observed even in the context of relatively good CS.



Across the group, CS decreased as stimulus complexity increased (simple figures: median 1.2, range 0.3-2.0; medium figures: median .5, range .0-1.7; complex figures: median .0, range .0-.7). A Friedman test found the effect of stimulus complexity on copy CS to be significant, $\chi 2$ (2) = 12.62, $p < .005$. Median copy CS for the Luria's figure was 0.5 (range .0-2.0).

A tendency toward more extreme CIB scores with increasing stimulus complexity was observed (simple figures: median 4.0, range 1.2–4.0; medium figures: median 4, range 1.7-4.0; complex figures: median 3.7, range 1.67-4.0), though a Friedman test was not significant, $\chi 2$ (2) = 4.1, p = .13. However, this null result does not necessarily imply that stimulus complexity does not influence CIB, since the analysis of the full dataset from which this data is drawn does reveal a significant worsening of CIB with stimulus complexity (see Chapter 4). The median CIB score for Luria's figure was 4.0 (range 1.0-4.0), with one instance of partial overlap, one of contact, and four instances of migration to within 10 mm of the model. A further two children produced copies that migrated markedly toward the model, though not passing the 10 mm proximity threshold required for classification with CIB according to our scale.

In summary, as would be expected for children in this age range (e.g. Gainotti, 1972; Mendilaharsu et al., 1970), graphic copying was somewhat inaccurate and copies tended to be placed close to the model. Individually, some relatively extreme examples of CIB (partial overlap) were observed, though there were no instances of complete overlap. Selected examples of CIB, associated both with relatively good and relatively poor CS are shown in Figure 7.1. These patterns suggest that CIB may, to some degree, be separable from constructional abilities *per se*.

Experimental task

Preliminary single tasks

Initially, the children were asked simply to copy straight black horizontal lines presented in landscape orientation. Each line was 232 mm long and 3 mm thick, and presented 25 mm from the top or bottom edge of the paper (see Figure 7.2). A 4 mm diameter back dot was centred vertically 25 mm from the left edge of the page. The instruction was to copy the line from left to right as straight as possible, starting with the pen on the black dot. Each child performed four trials, with position of the model manipulated according to an ABBA schedule, starting with the line at the top.

In this task, CIB was quantified as the average deviation of the drawn line from the horizontal. This was estimated by averaging the vertical coordinates of the line at

10 mm to the right of the start position and at successive rightward increments of 10 mm until the right hand edge of the paper was reached or the drawn line was no longer present. Deviations toward the top of the sheet were signed positively and deviations toward the bottom of the sheet were signed negatively, with the zero-level defined by the vertical midline of the page.

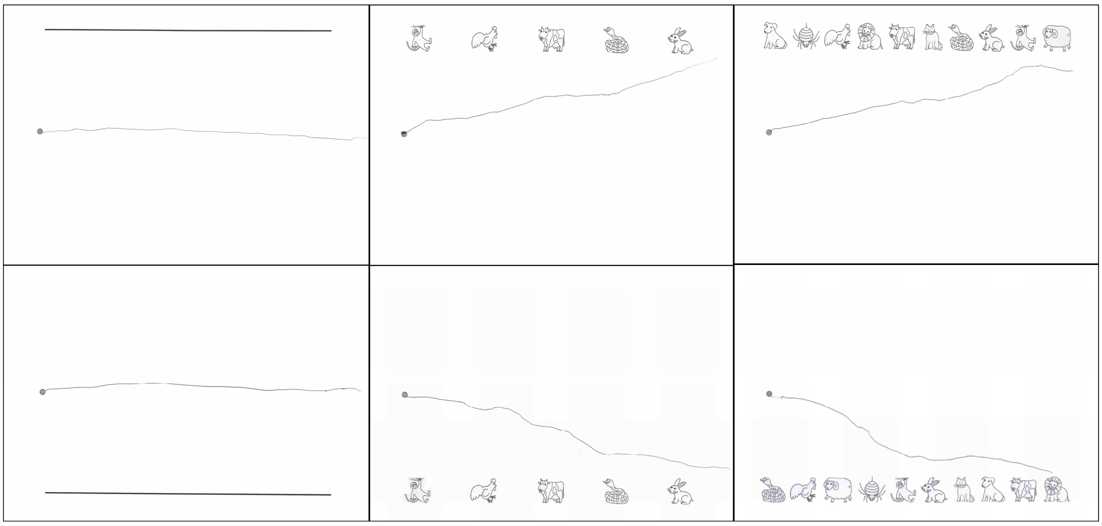
In a separate task, each child was asked to name some line drawings of animals (dog, cat, lion, snake, sheep, cow, spider, monkey, rabbit, and rooster). Each drawing was 20 mm high, printed in black on white. All children were able to recognize and name these animals satisfactorily, suggesting that this would constitute a suitably straightforward visual sub-task for the experiment to follow.

Experimental dual task

In the experimental dual task, the children were presented with a straight-line drawing task in conjunction with an animal-naming task (see Figure 7.2). On each trial, an A4 landscape sheet with a 4 mm black dot centred vertically 28 mm from the left edge was presented. A row of animal line-drawings was printed at the top or on the bottom of the sheet (16 mm from the top or bottom edge). In the 'low-density' condition, five animals were spaced evenly between 31 mm from the left and right edges of the sheet, and in the 'high-density' condition, ten animals were spaced evenly between 25 mm from the left and right edges of the sheet. The instruction was to start with the pen on the black dot, and to draw a straight line to the right hand edge of the sheet, naming any animals that the hand moved past. To assist with the naming task, the examiner pointed to each drawing that the hand moved past. Each child performed two blocks of 4 trials. In the first block, density was manipulated according to a repeating ABBA schedule, with the low-density condition first, and figure position alternated between trials, beginning with the animals at the top. This trial order was reversed in the second block and the order of the blocks was alternated between children.

Figure 7.2. Selected examples of graphic performance in the preliminary line-copying task (left panels), and in the dual task in which straight-line drawing was combined with animal naming: low-density (middle panels) and high-density (right panels) conditions.

The dual-task illustrations show vivid examples of migration toward the animal naming stimuli.



RESULTS

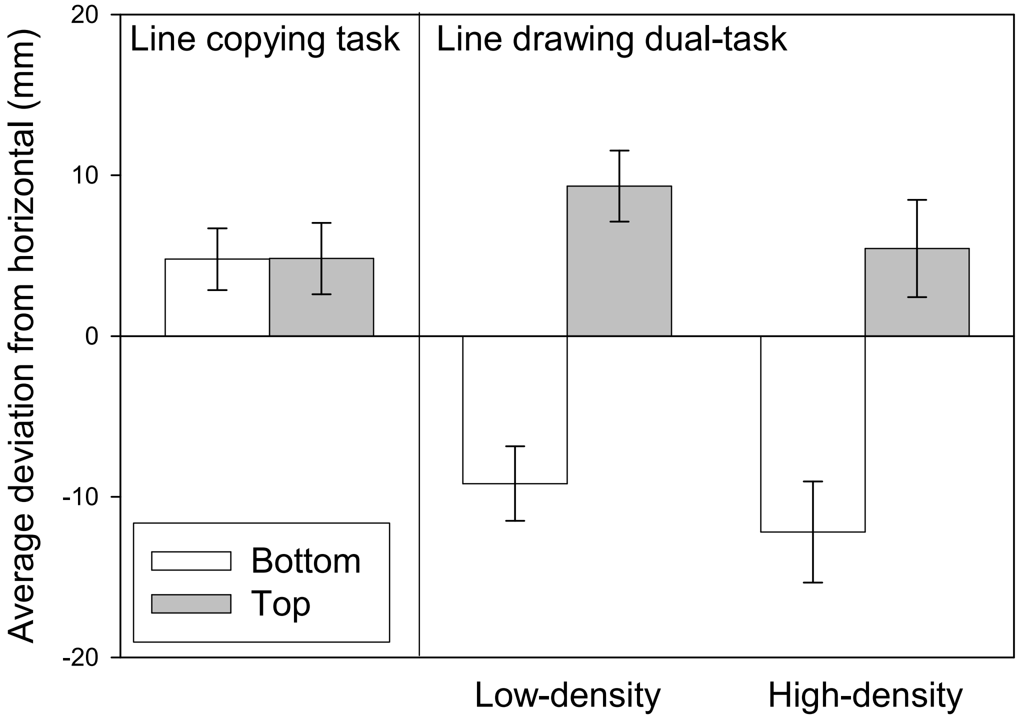
In the preliminary *single line copying task*, the children's copies deviated slightly toward the top of the sheet, regardless of position of the model (leftmost part of Figure 7.3). A paired t-test found no reliable difference between the mean deviations for the two model positions, t (14) = .02, p = .98. A one-sample t-test on the grand mean deviation (collapsed across model position) confirmed that the upward deviation was reliably greater than zero, t (14) = 2.49, p = .026. This overall tendency to veer toward the top of the sheet is of uncertain origin. However, it emphasises the importance of varying position of the model in the assessment of CIB, so that a true tendency to deviate toward the model can be disambiguated from broader default tendencies to deviate away from the centre of the page.

In the experimental *line drawing dual-task* (right side of Figure 7.3), an overall tendency to deviate toward the top of the page was again apparent, slightly more so in the low-density condition. But overlaid on this was a strong tendency to deviate toward the animals being named, regardless of density condition. A repeated-measures ANOVA by animal position (top, bottom) and density (low, high) confirmed these impressions, finding reliable main effects of both factors, position,

$F(1, 14) = 52.73$, $p < .001$, and density, $F(1, 14) = 4.74$, $p = .047$, but no reliable interaction, $F(1, 14) = .24$, p = .64.

Figure 7.3. Mean deviation of the drawn line away from the horizontal in each condition, where positive is above and negative is below the level of the starting point (page midline).

Unfilled and grey bars show performance with the model/naming stimuli at the bottom and top of the page respectively.



This deviation of drawn lines toward the location of visual attention defined by the naming task appears to mimic classical CIB, presumably depending upon similar underlying mechanisms. In order to investigate this point further, the relationship between induced deviation toward the animals in the dual-task, and spontaneous deviation toward the model during the preliminary copying tasks were evaluated. For this analysis, deviation of the preliminary copy of Luria's figure was quantified in the same way as the deviation of the line in the dual-task. For the dual-task, mean deviation in each condition was recorded as positive if it was toward the animals named and as negative if it was away from the animals named; a grand mean deviation was then calculated across conditions. Pearson's correlation coefficient between tasks was .55 (p = .035), indicating that CIB in the dual task could be predicted reliably from Luria's figure copying task. Deviation toward the animals in the dual task could also be predicted from the mean CIB score rated across the nine geometrical figures of the preliminary copying tasks (Spearmans *rho* = .61, p = .033). To explore the relationship between CS and CIB, correlation analysis was performed on the average scores of CS and CIB among the nine geometrical pictures copying task. This analysis showed that the two scores did not correlate significantly (Spearmans *rho* = -.17, p = .52). Same results were also obtained for Luria's copying task (Spearmans *rho* = .06, p = .81).

Relationship Preliminary line drawing task and dual task.

In order to explore the relationship between the performances in the preliminary task and in the dual task condition, correlation analysis was performed on the overall deviations from the horizontal (collapsed across model position) of line drawings in preliminary line drawing taks and dual task condition. The analysis showed that performances in these two conditions were not significantly correlated (Spearmans *rho* = .27, p = .33). This relationship was further explored, assessing if the performance in the dual task varied between children who showed different performance in the preliminary task. Both children who showed a line drawing bias towards the model position in the preliminary (n= 7) task and children who showed a bias away from the model (n= 8) did not differ in performance in the dual task condition ($t(13)$ = -.86, p = .40). This evidence suggests that performance in the dual task condition was independent from children's performance in the preliminary task.

DISCUSSION

The nature of graphic CIB was examined in 15 children aged between four and six years. In line with previous literature (Gainotti, 1972; Mendilaharsu et al., 1970) and the results of the previous chapter (from which this sample of children was extracted), the preliminary copying tasks confirmed the spontaneous occurrence of CIB in this age range, not tightly related to other aspects of copy quality, manifested chiefly as the placement of copies close to or touching the model, with occasional instances of partial overlap. In several children, the laterally extensive Luria's figure copying task elicited migration toward the model, as also observed in patients with AD (Lee et al., 2004, see also Chapter 3). Crucially, the experimental task, which combined simple straight-line drawing with concurrent visual naming, induced a similar migration. The extent of this migration in a given child was related reliably to prior copying of Luria's figure, and of more-standard geometric figures, suggesting that the present dual-task did not merely mimic CIB in copying, but actually elicited the same phenomenon. The migration of drawing performance toward an *unrelated* visual stimulus cannot be explained by the compensation hypothesis, which assumes that CIB is a strategic adaptation to aid copying. On the other hand, this result is predicted precisely by the attraction hypothesis, according to which manual performance in susceptible groups should be drawn toward any sufficiently absorbing focus of visual attention.

The present experiment tested between competing hypotheses that have been proposed to explain CIB in adults with dementia. This is not to assume that the same factors underlie CIB in dementia and development, only that the same set of hypotheses are applicable, in principle, to children and adults alike. Nonetheless, the clear parallels between the manifestations and progression of the phenomenon in these different populations have encouraged several researchers to view them as functionally related, not just superficially similar (De Ajuriguerra, 1960; Gainotti, 1972; Mendilaharsu et al., 1970). This possibility is bolstered by the fact that the present findings closely replicate some results obtained from a 62-year old woman (WS) with moderate AD and pronounced CIB (see Chapter 4). Patient WS performed a straight line drawing task concurrently with a letter-reading task, and veered markedly toward the letter stimuli, as predicted by the attraction hypothesis.

The alternation of visual naming stimuli between the top and bottom of the page in the present design allowed us to distinguish true migration toward those stimuli from other directional biases in drawing. Indeed, the straight line copying task performed prior to the main experiment revealed that the children tended to drift slightly (~5 mm) but significantly upward from their starting point, regardless of model position. A similar drift exists in healthy adults (Lee et al., 2004, see also Chapter 4 and 5), reminiscent perhaps of the distal attentional bias observed in normal subjects performing radial line bisection (Halligan & Marshall, 1993; Shelton, Bowers, & Heilman, 1990). If pronounced, such drift could masquerade as CIB whenever the model was at the top of the page. Therefore at least two model positions should be used for the assessment of this symptom (see Chapters 4, 5 and 8).

In addition to manipulating model position, the density of the visual naming stimuli was manipulated, with the expectation that the greater requirement for focused attention in naming stimuli in the high-density condition would amplify any manual migration effects. Instead, a simple main effect of stimulus density emerged, such that upward drift was reduced overall in the high-density condition. No principled account can be offered for this finding, but note that this main effect does not pertain at all to CIB, which was tested specifically by the effect of model position upon drawing position. The fact that the effect of model position (CIB) did not interact with stimulus density suggests that the difference between low- and high-density stimuli may have been too subtle to substantially alter the degree of visual monitoring of the animal naming stimuli (or that a ceiling level of monitoring was induced in the low-density condition). Alternatively, the examiner's finger, tracking progress along the row of stimuli, may have provided a constant visual focus that acted to minimise differences between low- and high-density conditions. A lack of modulation of CIB between low and high-density visual naming conditions was also observed in patient WS (Chapter 4), perhaps for similar reasons.

The similarity of the graphic performances of children and the patient WS supports the view that common factors underlie CIB in development and dementia. Having thus rejected the compensation hypothesis in children and in a patient with dementia, the next step was to specify the attraction hypothesis more fully. The hypothesis posits a default manual attraction toward the focus of visual attention. This idea resonates with research suggesting that attention-attracting visual stimuli recruit motor programs automatically, which must be actively suppressed in order to prevent responses toward these stimuli from contaminating ongoing behaviour (e.g. Tipper et al., 1998). However, the bare hypothesis does not state which cognitive factors promote the release of this default state. Kwon et al. (2002) have suggested that the crucial precipitant is a deficiency of executive and/or attentional resources.

Copying tasks may inherently possess the quality of a dual-task, requiring the efficient division or switching of attention between model and copy. A deficit in executive control, which would be needed to inhibit analysis of the model in order to switch attention to monitor copy production, could plausibly underlie the release of the default tendency to migrate toward the model.

In support of this view, the results of the previous chapter showed that the best predictor of CIB in Luria's figure copying task was the performance of the children in the attentional battery, and in particular the subtest which measured the ability of the children to switch between different roles. Moreover, it should be noted that CIB can indeed accompany deficits in the inhibition of automatic responses (Conson et al., 2009), and that it may be pronounced following a frontal lobe lesion (Lepore et al., 2005). The symptom has also been observed in frontal syndromes associated with epilepsy, both in children (Hernandez et al., 2002) and adults (Septien et al., 1992). Moreover, CIB in clock-copying (defined as a model-directed mislocation of numbers) amongst patients with mild dementia, has been found to be associated with white matter lesions and poor performance on executive tasks (Cosentino et al., 2004). The hypothesis that attentional and/or executive deficits underlie CIB, thus finds some support in the neuropsychological literature, and offers a tractable starting point for future investigations.

Of course, even if attentional and/or executive deficits are necessary for the emergence of CIB, it is likely that the behaviour could be exacerbated by other cognitive deficiencies that might co-exist with these problems. In general, a possible explanation might be that factors which increase the difficulty of the copying task will tend to amplify CIB by placing additional load upon the cognitive system. Such factors might be external to the system: for instance, increased figure complexity, which has several times been reported to exacerbate CIB (e.g. Lee et al., 2004; Mayer-Gross, 1935; Muncie, 1938) and has been confirmed in both patients with AD (see Chapter 4) and pre-school children (see Chapter 6). Alternatively, there might be internal factors, such as deficiencies of visuospatial abilities or working memory. These considerations suggest that the search for cognitive correlates of CIB could throw up multiple candidates. In accord with Kwon et al. (2002), however, a possible hypothesis is that the most powerful unique predictor of CIB should relate specifically to attentional and/or executive functions.

Finally, it is prudent to issue a caveat regarding the simulation of CIB that has been achieved in the present study. Although the dual task was successful in eliciting migration toward the visual focus, the effects were limited to this pattern of veering. Notably, no extreme examples of drawing or scribbling over the naming stimuli were induced. This could reflect a restriction inherent to the present sample, since the most extreme manifestations of CIB in the preliminary copying tasks were a few instances of partial overlap, and no overlap at all was observed for Luria's figure. Provided that migratory CIB (encroachment on the model) lies on a continuum of severity with the contact and overlap forms, then it might seem safe to assume that the present conclusions can generalise to the phenomenon as whole. However, the assumption that the different forms of CIB lie on a continuum, and share common causes, is still untested in pre-school children. Since the study previously reported in Chapter 3 and 6 suggests that CIB may have a common cognitive nature in patients with AD and pre-school children, it is possible to speculate that the results obtained with patients with AD may also account for CIB in pre-school children. If so, the overlap and the near-type of CIB in pre-school children may not simply lie on a continuum of severity, but reflect differential involvement of attention and visuospatial factors as in AD. This interpretation is speculative and further studies should be conducted to explore the cognitive aspects related to the two main types of CIB in pre-school children. At the moment, the present conclusion in favour of the attraction hypothesis should be taken to apply strictly to the more subtle, migratory form of CIB, and only tentatively to extend to more dramatic manifestations.

Finally, the present study has same limitation as Chapter 4, in that the experimental design allowed a direct test of the attraction hypothesis, but future studies should be designed to test the compensation hypothesis in preschool children. Moreover, the possibility that the compensation hypothesis might account for more dramatic forms of CIB, consisting in the tendency to trace the line of the model, cannot be excluded. As pointed out in Chapter 4, future studies should be designed to test whether the form of CIB characterized by a convertion of copying into tracing does represent a strategic compensation of viusospatial or working memory deficits, as postulated by the compensation hypothesis.

To conclude, the present study provides evidence supporting the attraction hypothesis of CIB in pre-school children, and that CIB is not specific to copying tasks, but is a more general phenomenon. The view that this behaviour betrays a specifically constructional deficit should, therefore, be re-evaluated. In addition, the results of the previous study (Chapter 6) suggest that the immaturity of the attentional abilities may be responsible of the release of the default tendency to respond toward the spatial focus of attention.

As previously described, in the present study the density of visual naming stimuli was manipulated as a further investigation of the attraction hypothesis of CIB, and several speculative interpretations have been proposed to explain the null results concerning this factor. In the next chapter, the inconsistency of this result is explored in more detail. More specific manipulations of the secondary task are presented in order to explore which characteristics and cognitive demands of the task are able to modulate the line drawing bias toward the focus of attention observed in the present study.

CHAPTER 8
Further assessment of closing-in behaviour in preschool children

INTRODUCTION

As described in the previous chapters, the first attempts of young children to copy drawings are often characterized by CIB. This is the tendency to copy very close to, or directly on the top of, the model. CIB is common in children of two-to-three years (75%), decreasing progressively between three and five, and disappearing around six years of age. The successful separation of the copy from the model seems to run a parallel course with the development of other aspects of constructional skills (Gainotti, 1972).

CIB is a normal, though not ubiquitous, feature in the development of graphic abilities. The phenomenon can also be observed in adults following brain damage from a wide variety of aetiologies (dementia, cerebral stroke, carbon monoxide poisoning, corticobasal degeneration, encephalitis, epilepsy) (De Ajuriaguerra et al., 1953; De Renzi, 1959; Denny-Brown, 1958; Kwon, Kang, Lee, Chin, Heilman, & Na, 2002; Lhermitte & Mouzon, 1941; Muncie, 1938; Stengel & Vienna, 1944; Vereecken, 1958). CIB is more common in dementia than following focal cerebral infarcts (Gainotti, 1972; see also De Ajuriaguerra et al., 1960). This symptom is relatively rare in mild dementia (6%), but becomes increasingly common with the progression of dementia through moderate (42%) and severe (61%) stages (estimates from Gainotti, 1972; see also De Ajuriaguerra et al., 1960). The increase in frequency of CIB with dementia severity is associated with the progressive deterioration of CS, thus mirror-reversing the developmental course seen in early childhood (Gainotti, 1972). These superficial similarities between CIB in dementia and in development suggest that common factors could be responsible in these two groups. That is, CIB may be linked to specific cognitive abilities, which develop in the first years of life and deteriorate progressively in dementia.

Two main accounts have been proposed to explain CIB. The first account considers the phenomenon as a compensatory strategy to overcome insufficiencies of visuo-spatial or memory abilities (Lee et al., 2004). According to this view, the copy is performed close to the model in order to reduce the visuo-perceptual and memory demands involved in transposing it to a remote location. The second account suggests that CIB is a primitive, default behaviour, characterized by an attraction of the acting hand toward the focus of attention (Ambron et al., 2009b; De Ajuriaguerra et al., 1960; Gainotti, 1972; Kwon et al., 2002; McIntosh et al., 2008). It has further been suggested that this primitive pattern might be especially likely to appear under conditions of reduced executive and/or attentional control (Kwon et al., 2002; McIntosh et al., 2008). Therefore, the compensation hypothesis proposes that CIB is an adaptive strategy, specific to copying tasks, while the attraction hypothesis considers CIB to be a more general default behaviour, often elicited by copying tasks.

In the previous chapter (see also Ambron et al., 2009b), the predictions of the attraction account of CIB were evaluated in 15 preschool children (four-to-six years), using a straight-line drawing task in conjunction with a concurrent picture naming task. The attraction hypothesis predicts that CIB should emerge in this dual task, despite the absence of any copying component, simply because visual attention must be focused at one location whilst the hand must act at a different location. The attraction account thus predicts the migration of line drawings toward the pictures being named, since these will tend to be the focus of visual attention. The results of this study supported the attraction hypothesis, finding a clear tendency for children's line drawings to migrate toward the pictures at the top or bottom of the sheet. This line drawing bias was correlated significantly with classic CIB in copying geometric shapes, and the laterally extended Luria's figure (Luria, 1966). It was concluded that the line drawing bias observed in this dual task condition mimicked CIB in graphic copying tasks.

Chapter 4 (see also McIntosh et al., 2008) elicited a similar manual bias toward the focus of attention in a patient with AD, consistent with a common basis for CIB in development and dementia. As noted above, it has been suggested that manual attraction to the focus of attention is a default tendency that emerges under conditions of reduced attentional resources (Kwon et al., 2002; McIntosh et al., 2008). Evidence supporting the important role of attention in the appearance of CIB in children has been provided by the study reported in Chapter 6, which explored the cognitive nature of CIB in pre-school children (see also Ambron et al., 2009b). A sample of 41 pre-school children were assessed for CIB on graphic copying, and also performed a cognitive battery of tests aimed at assessing visuo-spatial abilities, working memory, and attention (selective, sustained, and attention switching). The unique predictor of CIB, among the cognitive tasks, was the attentional battery. Moreover, the attentional switching task was the unique predictor of CIB among the attentional subtests. This test required the children to give a verbal or a motor response (name animals' pictures or clap the hands) to two sets of stimuli (picture of animals and pictures of animals heads), switching between two different rules. This evidence suggests that, in pre-school children, CIB is especially related to the inability to switch between two tasks, perhaps relating to the demands imposed by copying, where attention must be switched flexibly between visuo-spatial analysis of the model and graphic production of the copy.

Compatible results were obtained in the retrospective study of 797 patients with AD (Chapter 3, see also Ambron, et al., 2009c). In this large cohort, the most crucial factor responsible for the release of CIB was the performance in an attentional subtest, although visuo-spatial abilities were found to contribute to the prediction of very severe CIB, in which the copy is drawn directly on the top of the model. Therefore, these results are in line with the pre-school children study, reported in Chapter 6 (see also Ambron, et al., 2009b), which suggests that attention immaturity is the crucial factor in the release of CIB, and again consistent with similar underlying mechanisms in these two different populations.

A critical involvement of attention in CIB predicts that the phenomenon should be amplified when the attentional demands of the task are increased. The dual-task study presented in the previous chapter (see also Ambron, Della Sala & McIntosh, 2009b) incorporated an initial attempt to test this prediction, by manipulating the number of animals to be named in the secondary task. In the low-density condition, 10 animals were spaced across the sheet, while in the high-density condition there were 20 animals more closely spaced. It was predicted that there would be greater migration toward the animals in the high-density condition as a consequence of the greater demand for visual attention. However, this result was not obtained, with equivalent migration being induced in the two density conditions. It was suggested that the amount of visual attention required in the low-density condition could have been already sufficient to induce a ceiling level of monitoring, explaining this lack of modulation in the CIB degree between the two attentional load conditions. In addition, in that study, a possible confound was that both spatial density and number of animals varied between conditions.

The present study is an attempt to extend the results of Chapter 7 (see also Ambron et al., 2009b) to different secondary tasks and to assess, for the first time, the impact of attention capture and of different degrees of attentional load upon CIB in children. Four experiments therefore consisted of adapted versions of the dual-task: a straight line drawing task in conjunction with a secondary visuo-spatial task, which involved responding to animal pictures. The first aim was to assess if a migration of line drawing toward the animal stimuli would appear in every condition. This evidence would strongly support the attraction hypothesis of CIB, by demonstrating that any manipulation, requiring visual attention to be focused at one location while a motor response is performed at a different location, is sufficient to induce a manual bias toward the focus of attention.

The second aim was to investigate the prediction of the attraction hypothesis that the manual bias toward the focus of visual attention should be exacerbated by increasing the difficulty of the secondary task. Therefore, it is predicted that the line drawing migration toward the animals' position would be higher when the children are required to perform more complex secondary tasks. Finally, the present study aimed to manipulate the characteristics of the stimuli and the cognitive demand associated with the secondary naming task in a variety of different ways, in order to further investigate the lack of modulation of CIB with the attentional load observed in the study reported in Chapter 7 (see also Ambron et al., 2009b). Moreover, according to the idea that depletion of attentional resources is critical to the emergence of CIB, it was expected that strong effects would be seen, not only when the secondary task difficulty would be manipulated via a change of attentional demands (Conson et al., 2009; Kwon et al., 2002; McIntosh et al., 2008), but also when attention might be automatically captured by relevant stimuli.

In Experiment 1, the perceptual salience of the animals was manipulated. Stimuli of higher perceptual salience (different colours) are more likely to capture the visual attention of children than low perceptual salience (black and white) pictures. Therefore, a larger line-drawing bias toward the animals in the high salience condition compared to the low salience condition, was expected as a consequence of the greater visual attention paid to the stimuli.

In Experiment 2, the number of response switches required in the animal-naming secondary task was manipulated. This manipulation was based upon previous observations of a relation between CIB and the immaturity of the attention switching system in children (Chapter 6; see also Ambron, McIntosh, & Della Sala, S., 2009d). This previous evidence suggested that under conditions of high response-switching requirement CIB is more likely to appear, and predicts that the magnitude of line-drawing bias will be greater when the secondary task requires switching attention between two stimuli than in a condition in which attention switching is not required.

In Experiment 3, the difficulty of the task was manipulated by simultaneously increasing the requirement for response inhibition and decreasing the salience of the stimuli. The aim of this experiment was to assess the relative roles of the above factors in the modulation of CIB. Specifically, the stimuli were prepared in such a way as to increase the requirement for inhibition across three conditions (low, medium, high) while at the same time decreasing the perceptual salience of the stimuli (high, medium, low). If the perceptual salience of the stimuli, with its capacity to automatically capture attention, is a more important factor in the modulation of CIB, the line drawing bias toward the stimuli should progressively decrease between high, medium and low perceptual salience. An opposite trend of increase in CIB magnitude between low, medium and high response inhibition is expected to be observed if the response inhibition plays the more important role.

Finally in Experiment 4, the memory demand rather than the attentional load, of the secondary task was manipulated. In all the previous experiments, children were required to implicitly recognize and name the animals. However, almost nothing is known as to the specific role of recognition memory processes in the modulation of CIB. Therefore, children were asked to perform old/new recognition or naming tasks. If memory demand plays a role in CIB, then a higher magnitude of

CIB in the more complex naming task (which requires an active search in memory of the animals to be named), than in the old/new recognition task (which requires a simple familiarity judgement), should be found.

To summarize, the main goals of the present study were (i) to show that a manual bias toward the focus of attention is consistent in tasks requiring the focusing of attention at one location and the performance of an action at another, independently from the manipulation of the secondary task; (ii) to investigate whether this manual bias can be amplified when the demands of the secondary task are increased; and (iii) to explore if specific characteristics of the stimuli in the secondary task further modulate this manual bias.

METHOD

Participants and design

Sixteen preschool children[18] (7 males and 8 females) were tested at a day nursery. The age range of the sample was 3.42-5.25 years (mean age 4.4 years, *SD* = 0.55). As for the study reported in Chapter 6, no information was recorded about the handedness of the children at the date of testing. The children were tested in the presence of nursery staff. The tests were presented as a ‘game’ that the children were invited to play with the examiner. All the children completed four experiments, each on a different day. Each experiment took about 15 minutes. The order of completion of the four experiments was counterbalanced across subjects using a Latin square design, to control for any order effects.

A further eight children (5 males and 3 females; age range 4.25-5.42, mean age 4.8 years, *SD* = 0.46) were later recruited in a different day nursery. This group of children performed Experiment 3 only.

This study received ethical approval from the Ethics Committee of the School of Philosophy, Psychology and Language Sciences, University of Edinburgh. The agreement of the legal representatives of the children was obtained before children were invited to participate.

[18] This sample of children did not take part in the study described in the previous chaper.

Experimental tasks

Preliminary line-copying task

Children were asked to copy straight black horizontal lines presented in landscape orientation. Each line was 265 mm long and 1 mm thick, presented 20 mm from the top or bottom edge of the paper. A small line (1 mm × 5 mm) was centred vertically 18 mm from the left edge of the A4 sheet of paper. Children were instructed to copy the straight line from the left to the right, making the line as straight as possible, starting with the pen on the small line. Each child performed two trials in each experimental session for a total of eight trials, starting with the model at the top.

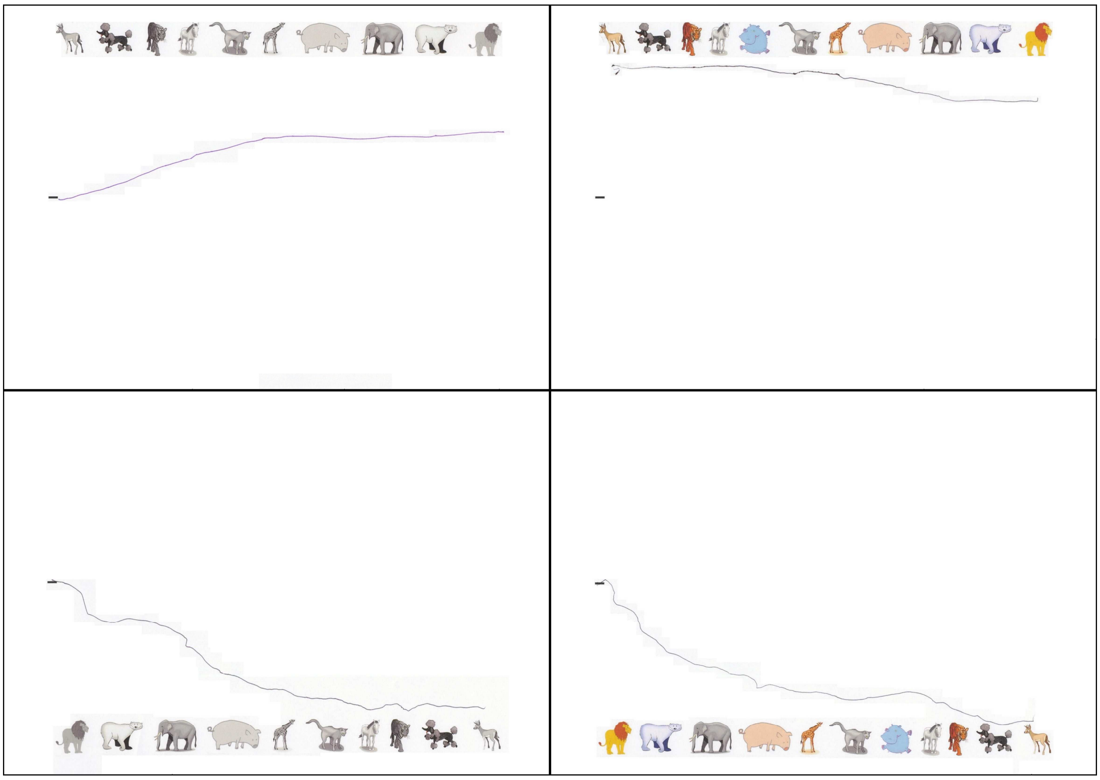
As in the study presented in the previous chapter (see also Ambron et al., 2009b), CIB was quantified as the average deviation of the drawn line from the horizontal axis. This was estimated by averaging the vertical coordinates of the line at 10 mm to the right of the start position and at successive rightward increments of 10 mm until the right hand edge of the paper was reached or the drawn line was no longer present. Deviations toward the top of the sheet were signed positively and deviations toward the bottom of the sheet were signed negatively, with the zero-level defined by the vertical midline of the page.

Dual tasks

In the dual task, children were asked to complete four different experiments. In each experiment, an A4 sheet of paper in a landscape orientation, with a small line (1 mm × 5 mm) centred vertically 18 mm from the left edge of the paper, was presented. A row of animal line drawings was printed 6 mm from the top or on the bottom of the sheet. In all experiments, ten animal line drawings were spaced evenly between 19 mm from the left and right edges of the sheet. The number of animals presented was constant across experiments, but the identity and the colours of the animals varied. The primary task remained the same across experiments and consisted of drawing a line from left to right as straight as possible, starting with the pen on the small line. The secondary task was varied in a different way within each experiment to manipulate: the perceptual salience of the stimuli (Experiment 1), the memory demand (Experiment 2), the number of response switches (Experiment 3) and the requirement for response inhibition (Experiment 4). To assist with the secondary task, the examiner pointed to each drawing that the hand moved past.

<u>*In Experiment 1*</u>, the perceptual salience of the animals to be named was manipulated. In the low-salience condition, the animals were printed in black and white (Figure 8.1), while in the high-salience condition, the same animals were presented in different bright colours. In both conditions, the animals were: a lion, polar bear, elephant, pig, giraffe, cat, hippopotamus, horse, tiger, dog, and deer.

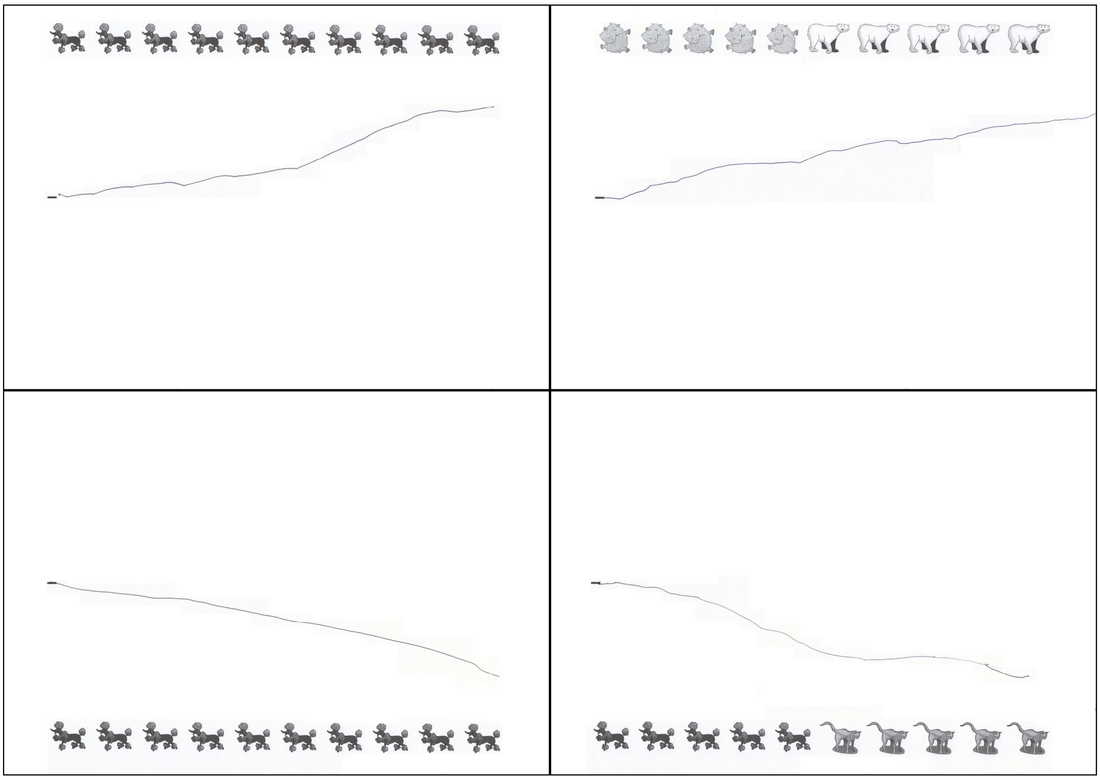
Figure 8.1. Examples of maximum performance in the low (left panel) and high (right panel) perceptual salience conditions, with the stimuli presented on the top (top row) and bottom (bottom row) of the sheet of paper.



<u>*In Experiment 2*</u>, the number of response switches required in the secondary task was manipulated. In one condition, children were asked to name a single black and white animal printed ten times on the top or on the bottom of the sheet (no-switch condition) (Figure 8.2). In another condition, two different animals were presented in ordered sequence of five drawings for each animal. In this condition,

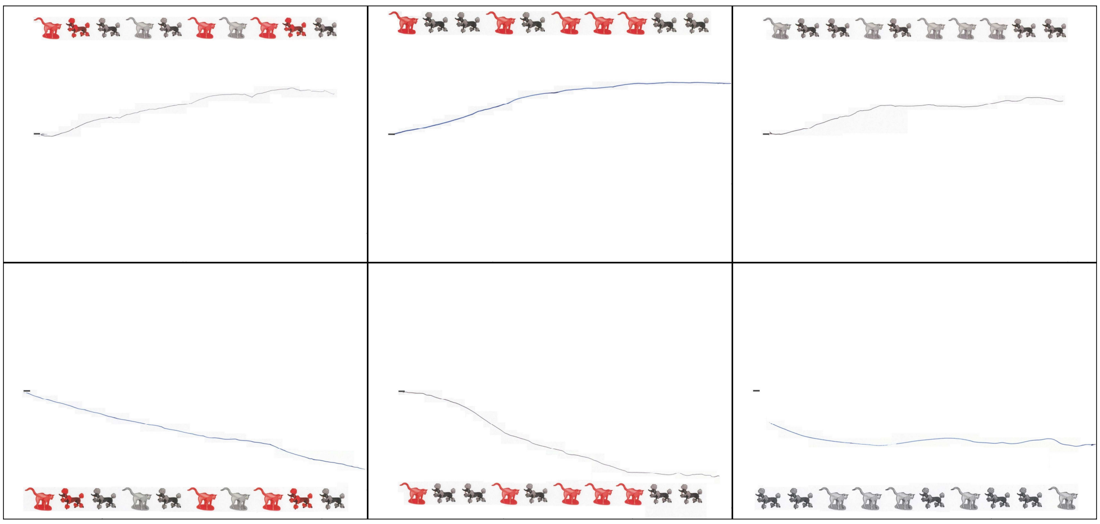
one response switch was required in order to switch between naming the first and the second animal. The animals were: cat, dog, polar bear, and hippopotamus.

Figure 8.2. Examples of maximum performance in the no-switch (left panel) and one switch (right panel) perceptual salience conditions, with the stimuli presented on the top (top row) and bottom (bottom row) of the sheet of paper.



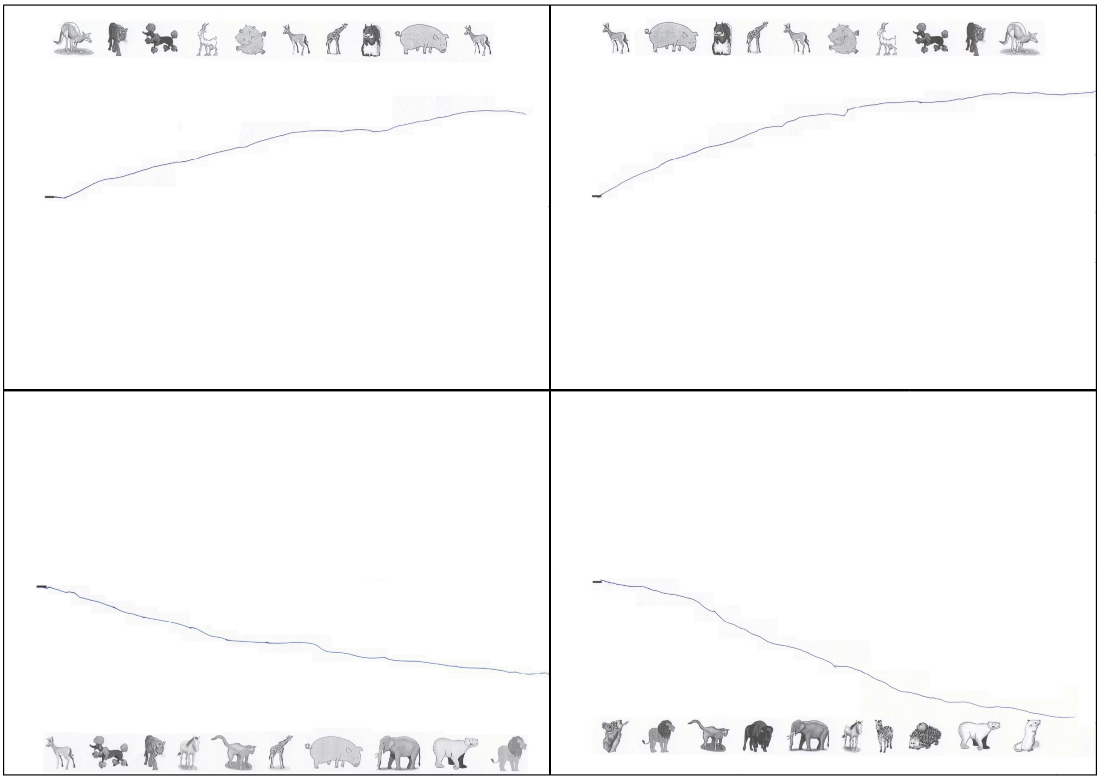
In Experiment 3, the secondary task was performed in three different conditions, which simultaneously changed the perceptual salience of the stimuli and the requirement for response inhibition. In the first condition, the line of animal drawings was a randomly-shuffled sequence of five dogs and five cats printed randomly in black and white or red ink. The children's task was to name each red animal as the hand moved past them (high perceptual salience/low response inhibition). In the second condition, the same sequence of animal line drawings was presented but only the cats were printed in red and children were asked to name just the red cats as the hand moved past (medium perceptual salience/medium response inhibition). In the third condition, the line of animal drawings was a randomly-shuffled sequence of five dogs and five cats printed in black and white (Figure 8.3). In this condition, children were instructed to name just the dogs as the hand moved past, refraining from responding to the cats (low perceptual salience/high response inhibition). Therefore, naming the red stimuli, irrespectively of their category, should require less control for inhibition, due to the high perceptual salience of the stimuli to be named, which involves a more automatic form of response with a low requirement for inhibition. In the medium perceptual salience/medium response inhibition, the stimuli to be named are still salient, but the category of the animals to be named is restricted to red cats only, hence implying no response to dogs and to non-red cats. In this condition, the level of response inhibition is supposed to be higher than in the previous condition, becoming more controlled. Finally, in the low perceptual salience/high response inhibition condition, the stimuli were not presented with any distinctive colour and the task involved a response toward a specific category of animals (dog), thereby implying a higher level of response inhibition toward the other non-salient category of animals (cats).

Figure 8.3. Examples of maximum performance in the high perceptual salience/low response inhibition (left panel), medium perceptual salience/medium response inhibition (central panel) and low perceptual salience/high response inhibition condition (right panel) conditions, with the stimuli presented on the top (top row) and bottom (bottom row) of the sheet of paper.



In Experiment 4, the memory requirement of the secondary task was manipulated. In the low-demand condition, the children were asked to recognize different animals printed in black and white. Children were instructed to respond *yes* if they recognized the animal and *no* if they did not. In the high memory demand condition, children were presented with the same animals, but their task was to name the animals (Figure 8.4). The to-be-named stimuli in this experiment were the same as in Experiment 1 with the addition of animals chosen to be less common, and thus more difficult to name than those used in Experiment 1 (kangaroo, goat, squirrel, koala, buffalo, zebra, mouse, and hedgehog).

Figure 8.4. Examples of maximum performance in the low (left panel) and high (right panel) perceptual salience conditions, with the stimuli presented on the top (top row) and bottom (bottom row) of the sheet of paper.



In each experiment, children performed two blocks of 4 trials per condition. Within a block, the order of the trials was manipulated according to a repeating ABBA schedule (an ABCCBA schedule for Experiment 4), and animal position was alternated between trials, with the first trial condition counterbalanced across children, to control for any order effects. The trial order was reversed in the second block. In all four experiments, CIB was quantified in the same way as for the preliminary line-drawing task.

RESULTS

Preliminary copying task

In the preliminary line-copying task, the children's lines deviated slightly toward the top of the sheet, both when the model line was placed at the top (mean=3.4; SD = 5.53) and at the bottom (mean = 2.11; SD = 5.18). This upward deviation was significantly higher when the model was at the top, $t(23) = 2.63$, p = .015, thereby demonstrating a subtle but reliable tendency to migrate toward the model (i.e. CIB), even for this very simple straight line-copying task.

Experimental dual tasks

In the experimental dual tasks, an overall tendency for the drawn line to deviate toward the animals appeared in all the conditions. As shown in Table 8.1, in every condition of each experiment, the performance of the children deviated toward the top of the sheet (signed positively) when the animals were presented on the top and toward the bottom of the sheet (signed negatively) when the animals were presented on the bottom. The specific analyses of each experiment were then carried out on mean deviations from the horizontal (collapsed across model position) for each condition. One sample t-tests computed on mean deviations toward the animals (collapsed across model position) confirmed that the deviation was significantly different from zero in all the experimental conditions (see Table 8.1). This robustly replicates the basic phenomenon demonstrated in the previous chapter (see also Ambron et al., 2009b), of manual attraction toward the focus of visual attention, even when the task is not one of copying.

Table 8.1. Mean deviation of the line drawing from the horizontal (collapsed across animals' position) in all the experiments. The asterisks indicate the *p* values results of one sample t-test against zero.

		Mean Deviation (Mean and *SD*)
Experiment 1	Low salience	5.90 (7.20)*
	High salience	8.68 (8.07)**
Experiment 2	No response switching	3.54 (4.12)***
	One response switching	7.44 (6.93)***
Experiment 3	High perceptual salience - low response inhibition conditions	6.46 (6.71)**
	Medium perceptual salience - medium response inhibition conditions	7.25 (6.65)**
	Low perceptual salience - high response inhibition conditions	8.12 (7.20)***
Experiment 4	Recognition	6.26 (6.71)**
	Naming	7.16 (8.63)*

*p<0.01; **p<0.005; ***p<0.001

In Experiment 1, a tendency to deviate toward the animals being named appeared when the stimuli were printed on the top and on the bottom of the page and was greater when the animals were printed in different colours than when they were printed in black and white (see Figure 8.5). A 2 (perceptual salience – low, high) by 2 (animals' position - top, bottom) repeated-measures ANOVA confirmed this evidence. The analysis showed a significant main effect of the position, $F(1,15) = 16.41$, $p = .001$, and a significant interaction between perceptual salience and position, $F(1,15) = 4.57$, $p = .049$. In order to further assess this significant interaction, a paired sample t-test was conducted on the mean deviation of the line drawing collapsed across the model position. The analysis confirmed a reliable difference between low and high salience conditions, $t(15) = 2.13$, $p = .049$. This result suggests that children's attention is captured more strongly when the perceptual salience of the stimuli is higher, increasing the tendency to migrate toward the focus of attention. Children were able to name 96% of the animals in the low salience condition and 97% of the animals in the high salience condition, indicating that they were performing the secondary task as instructed.

Figure 8.5. Mean deviation of the drawn line away from the horizontal in low and high perceptual salience conditions.

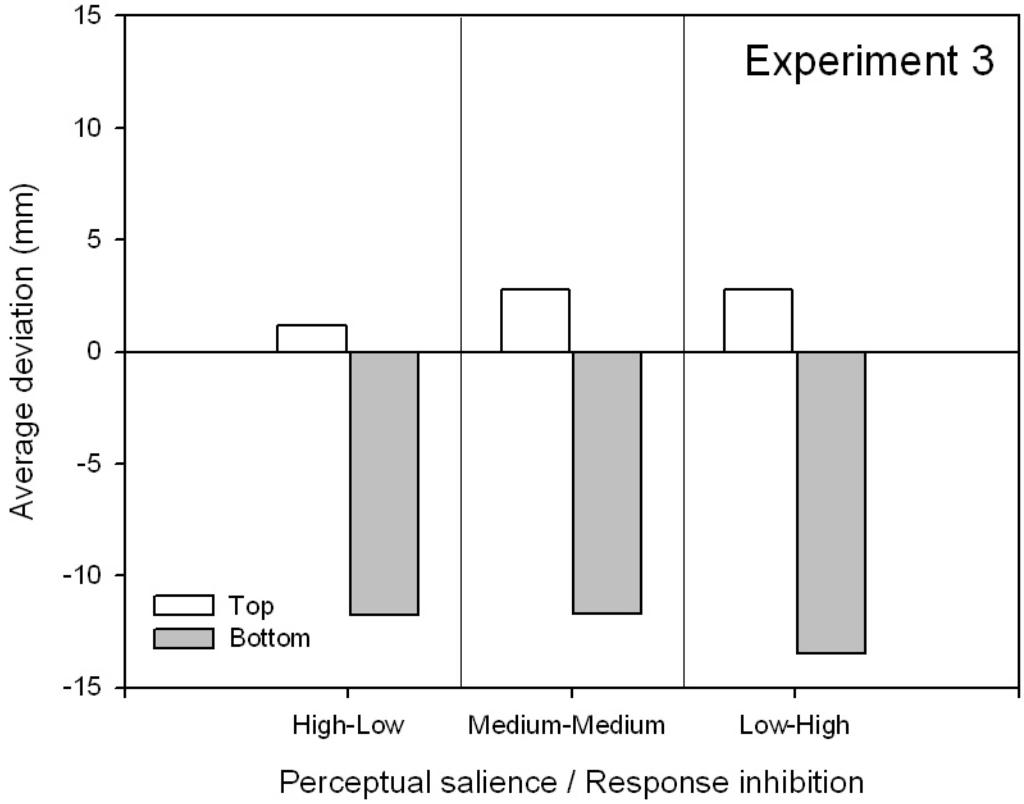
In Experiment 2 a tendency to deviate toward the animals being named appeared when the stimuli were printed on the top and on the bottom of the page and was significantly higher in the switch condition as compared to the no-switch (see Figure 8.6) as confirmed by a repeated-measures ANOVA with response switches (no-switch, switch) and animals position as independent variables, which showed a significant main effect of the position, $F(1,23) = 31.46$, $p < .001$, and a significant interaction between response switches and position, $F(1,23) = 9.56$, $p = .005$. Post hoc tests on the mean deviation of the line drawing collapsed across the model position confirmed that the tendency to migrate toward the animals was significantly higher in the switch condition as compared to the no-switch condition, $t(23) = -3.092$, $p = .005$. Moreover, a trend toward significance was found for the main effect of response switches, $F(1,23) = 3.91$, $p = .06$. Children named 96% of the animals in the no- switch condition and 98% of the animals in the switch condition, indicating that they were performing the secondary task as instructed.

Further analysis was conducted to examine CIB before and after the precise point of the stimulus switches (after 5 animals). A two-way repeated-measures ANOVA, with point of switch (before, after) and response switches (no-switch, switch) as independent variables was conducted on the mean deviation from the horizontal collapsed across model position. This analysis showed a significant main effect of the point of switch, $F(1,23) = 31.06$, $p < .001$, and of the response switches, $F(1,23) = 9.69$, $p = .005$. The line drawing bias toward the stimuli was higher after the point of switch, rather than before this point, and this effect was evident only in the switch condition. A trend toward significance was found for the interaction between point of switch and response switches, $F(1,23) = 3.90$, $p = .060$.

Figure 8.6. Mean deviation of the drawn line away from the horizontal in no-switch and switch conditions.

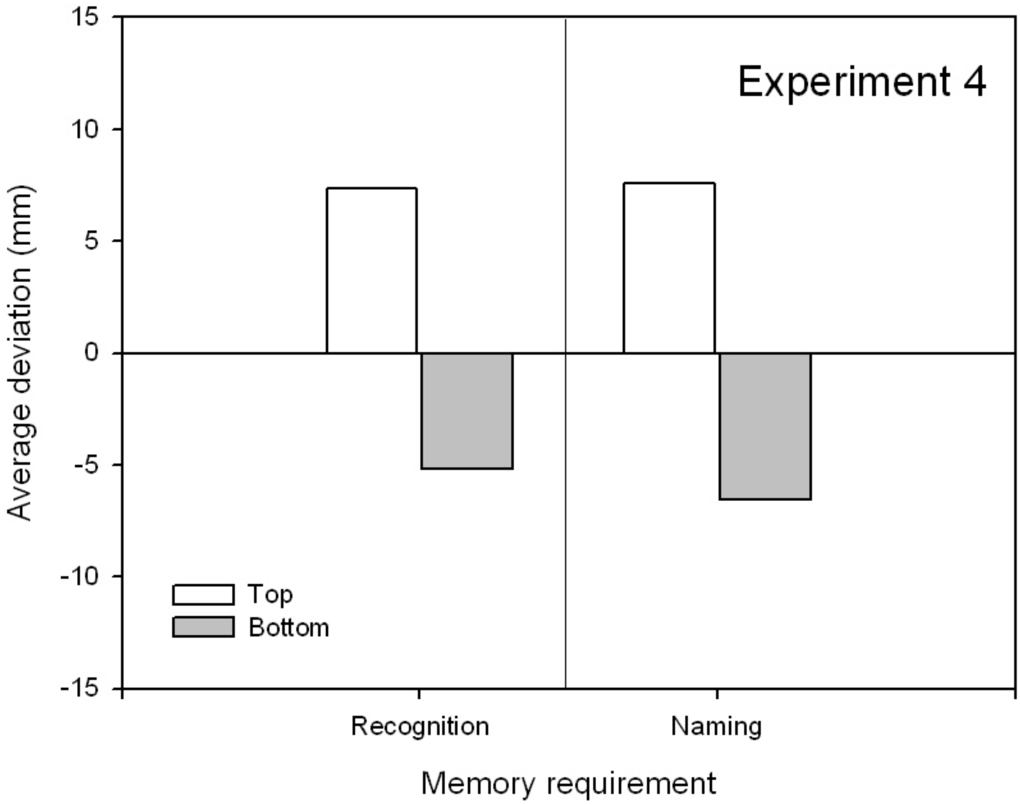
<u>In Experiment 3</u>, the line drawing bias toward the animals being named appeared when the stimuli were printed on the top and on the bottom of the page and progressively increased from high perceptual salience/low response inhibition, to low perceptual salience/high response inhibition (see Figure 8.7). A 2-way repeated-measures ANOVA was calculated for response inhibition (low, medium, high) by animals' position (top, bottom) which showed a significant main effect of the position, $F(1,15) = 19.54$, $p < .001$, but no significant interaction between response inhibition and animals' position, $F(1,15) = 2.02$, $p = .15$, or main effect of response inhibition, $F(1,15) = .74$, $p = .74$. However, the linear trend from low to high inhibition, irrespective of position, was very close to significance, $F(1, 15) = 4.053$, $p = .053$. Children named 99%, 96% and 100% of the animals in respectively the low, medium and high response inhibition conditions, indicating that they were performing the secondary task as instructed.

Figure 8.7. Mean deviation of the drawn line away from the horizontal in high-low, medium-medium, and low-high perceptual salience/response inhibition conditions.



In Experiment 4 a tendency to deviate toward the animals being named appeared when the stimuli were printed on the top and on the bottom of the page and was similar in both naming and recognition tasks (see Figure 8.8). A repeated-measures ANOVA with memory load (low, high) and animals' position (top, bottom) as independent variables showed a significant main effect of the position, $F(1,15) = 14.83$, $p = .002$, but no significant interaction between memory load and position, $F(1,15) = .28$, $p = .59$, or main effect of memory load, $F(1,15) = .72$, $p = .79$. Thus, the simple presence of a secondary task induced significant CIB, but its magnitude was unaffected by whether the children were asked to provide a familiarity judgment of the stimuli or perform a more active search in memory to name the animals. Children were able to recognize 94%, and to name 92% of the animals, indicating that they were performing the secondary task as instructed.

Figure 8.8. Mean deviation of the drawn line away from the horizontal in recognition and naming conditions.



DISCUSSION

The tendency to perform the line drawings toward the stimuli position appeared in all four of the present experiments. This consistently replicates the basic observation reported in the previous chapter (see also Ambron et al., 2009b), supporting the hypothesis that CIB is a primitive default behaviour characterized by a manual attraction toward the focus of attention. Importantly, the appearance of this behaviour in the dual-task, which requires a drawing task in conjunction with an unrelated secondary task, demonstrates that the phenomenon is not specific to copying tasks, although it has classically been defined in terms of copying behaviour. In fact, in the study described in Chapter 7, the manual bias appearing in the dual task experiment was highly correlated with the line drawing migration of Luria's figure, implying that this dual task did not merely mimic CIB in copying, but actually evoked the same phenomenon.

The second aim of the present study was to assess if this manual bias is amplified when the demands of the task are increased. Therefore, the characteristics of the stimuli and the demand of the secondary tasks were varied to explore if specific attention-related manipulations, rather than the density of the stimuli, were more likely to modulate this manual bias. In contrast with the results of Chapter 7, (see also Ambron et al., 2009b), this study showed that a modulation of the line drawing bias can be induced by increasing the complexity of the secondary task. However, in this context, the increase in complexity of the secondary task did not derive simply from the increase of a general cognitive load, but also from specific manipulations aimed at automatically capturing visual attention. This evidence is directly linked with the third aim of this study, which was to explore which cognitive factors would influence the degree of CIB. As recent studies (Conson et al., 2009; Kwon et al 2002; McIntosh et al., 2008) suggested, attentional and/or executive resources might promote the release of this manual attraction. In the present research, the magnitude of observed CIB increased with increasing level of cognitive demand only in those experiments where the attentional load (but not the memory retrieval load) was manipulated. In Experiment 1, the simple manipulation was to make the stimuli brightly coloured, rather than black and white, and thus more engaging of visual attention. Even this simple perceptual manipulation induced greater manual migration. In Experiment 2, the critical manipulation was the introduction of a switch in the required response by changing the identity of the animal named half-way along the sheet, and this single response switch led to increase CIB. Evidence from Experiments 1 and 2 supports the attraction hypothesis of CIB, which posits the appearance of a greater line drawing bias in conditions of higher attentional load.

In Experiment 3, the simultaneous manipulation of perceptual salience and response inhibition aimed to increase the executive control demand of the secondary task. A greater requirement of executive control was expected to induce a greater migration toward the focus of attention. Indeed, Kwon et al (2002) suggested the involvement of executive control in the release of CIB (Gainotti, 1972; Lepore, Conson, Grossi, & Trojano, 2005). The hypothesis of a possible connection between frontal inhibitory mechanisms and CIB was stimulated by the appearance of CIB in adults with frontal lobe damage (Septien, Giroud, Sautreaux, & Dumas, 1992;

Lepore et al., 2005), as well as in children with frontal lobe epilepsy (Hernandez et al., 2002). Although no significant interaction between the level of perceptual salience/response inhibition and the position of the stimuli emerged from the overall ANOVA, the linear trend was close to significance. This finding suggests that the increase of executive control exerted some influence on the magnitude of CIB. However, the manipulation across the three conditions might have been too subtle to induce a substantial variation on each of the three levels of response inhibition. On the other hand, this result does not support the attraction hypothesis and could be interpreted by exclusion as supportive evidence of the compensation hypothesis, which did not predict an increase of CIB with the increase of executive control required in the secondary task.

A significant modulation of the line drawing bias between the different levels of complexity of the secondary task did not appear in Experiment 4. Of course, it is always difficult to interpret null findings in dual-task experiments. However, the present lack of a significant modulation of CIB in Experiment 4 might suggest that the memory demand related to the identification of the pictures by their names might not be crucial for CIB. Indeed, the involvement of memory retrieval processes in CIB would have been confirmed if the magnitude of CIB had been greater in the naming task (which required an active search in memory in order to name the animals), than in the recognition task (which required a familiarity judgment based on the feeling of knowing). Notably, this was not the case in Experiment 4. Of course, this interpretation remains speculative and further studies are necessary to clarify this issue. It is possible that other memory processes are involved in the modulation of CIB. Future experiments should be designed to further investigate the possible role of the memory components in the modulation of CIB.

In the present study, CIB magnitude varied with the manipulation of the response switching and perceptual salience, hence supporting the hypothesis that this manual bias increases with higher attention directed toward visual stimuli. Salient stimuli drive attention and increase the amount of concentration on the stimuli. Experiment 2 showed that CIB is sensitive to the attentional load of the secondary task and that the magnitude of CIB is higher when the children are required to switch the response between two stimuli than when no attentional switching is required.

This supports an explanation of the emergence of CIB in terms of the involvement of the ability to switch attention (Chapter 6; see also Ambron et al., 2009d;). Experiment 3 suggests that CIB might be sensitive to the executive control of the secondary task, but a stronger manipulation of the secondary task is required. Experiment 4 confirmed that memory retrieval manipulations do not affect the magnitude of CIB.

However, it should be noted that an important aim of the study was to assess the attraction hypothesis. Therefore, the four experiments were designed independently from each other to modulate the magnitude of CIB targeting different cognitive abilities in the secondary tasks and were not explicitly matched for complexity. For this reason, a direct comparison between the experiments was not possible, and conclusions about which manipulation was more effective are necessarily tentative and exploratory.

To summarize, the present study provides further evidence in favour of the attraction account of CIB, showing that a dual task that requires focused visual attention at a location displaced from the proper space of drawing is able to induce a manual bias in that direction. This manual bias is sensitive to the cognitive load imposed by the secondary task. Most importantly, the present study provides initial experimental evidence that CIB is especially sensitive to task demands loading on attentional factors. However, these results are not unambiguous, since the manipulation of the secondary task, which loaded upon executive functions, was not successful in modulating CIB.

In these last two sections, the attraction hypothesis of CIB has received supportive evidence from studies conducted with patients with dementia and pre-school children. Since this hypothesis proposes that CIB is a primitive default behaviour, it predicts that normal participants would show a similar default tendency in some task conditions. Therefore, two studies conducted with normal participants will be presented in the next two chapters. In Chapter 9, the possibility that normal participants may show a manual bias toward the model will be assessed using a graphic copying task, while in Chapter 10 this hypothesis will be tested using a dual task condition and a more precise methodology to record hand movements.

SECTION 3

EXPLORING CLOSING-IN BEHAVIOUR IN NORMAL PARTICIPANTS

CHAPTER 9
Eliciting a manual bias in graphic copying in normal participants

INTRODUCTION

In previous chapters, a series of studies on CIB in patients with dementia and children were presented. These studies produced converging evidence for the attraction hypothesis of CIB, which regards CIB as a primitive default behaviour characterized by a manual attraction toward the focus of attention (Lee et al., 2004). It has been proposed that attentional and/or executive deficits might cause difficulties in monitoring the manual performance, particularly switching attention between analysis of the model and copy production. The inadequate manual monitoring could cause the merging of the two tasks (visuospatial analysis and manual performance) with a consequent migration of manual performance towards the focus of visual attention. Moreover, it has been suggested that this manual bias is likely to be exacerbated when the task becomes more difficult, either as a consequence of cognitive impairment, which renders a patient less able to perform a given task, or due to the intrinsic cognitive demands of the task (see Chapter 4). Since the attraction hypothesis proposes that CIB is a *default* behaviour, a further prediction is that a manual bias toward the focus of attention should be elicited in normal participants under some task conditions. Thus the present study was carried out to explore whether a drawing bias toward the model position might emerge for a complex graphic copying task in normal participants, following a preliminary series of pilot studies.

The second aim of the present study was to test a further prediction of the attraction hypothesis of CIB, which proposed that deficiency in attentional and/or executive resources should precipitate this manual attraction toward the focus of attention (Kwon, 2002; Gainotti, 1972). In Chapter 4, this hypothesis was further developed and it was proposed that attentional and/or executive deficits might reduce monitoring of the manual performance, with the consequent release of the default tendency to migrate toward the attentional focus. This hypothesis would therefore, predict that a manual bias toward the focus of attention in normal participants is more likely to appear under conditions in which monitoring of manual performance is hampered. Monitoring of manual performance relies on visual monitoring and proprioceptive information (Rossetti, Stelmach, Desmurget, Prablanc, & Jeannerod, 1994). This last source of manual monitoring can be compromised in deafferented patients (Rothwell, Traub, Day, Obeso, Thomas, & Marsden, 1982), but it is difficult to alter in an experimental setting and would have required the use of tendon vibration (Redon, Hay, & Velay, 1991). Due to this constraint, only visual monitoring was manipulated in the present study. Participants were asked to perform graphic copying with or without visual feedback of their manual and graphic performance, with the prediction of increased manual bias in the no-vision compared to the vision condition.

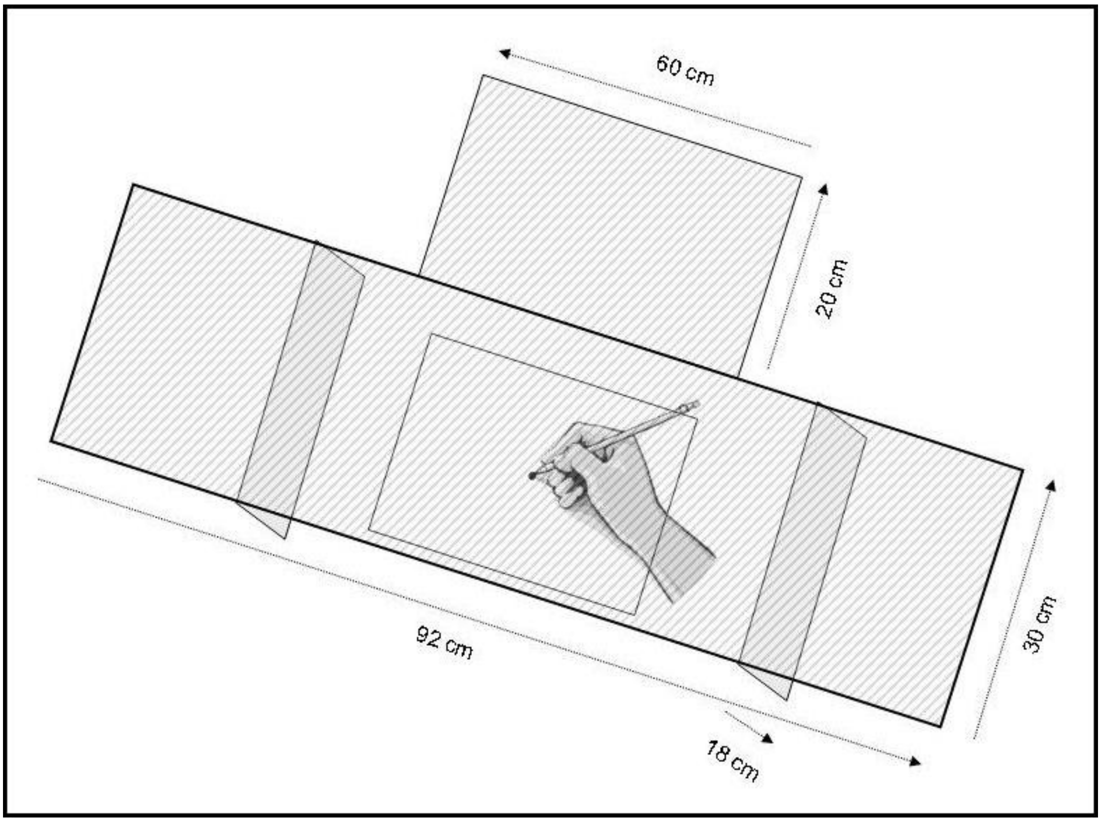
MATERIAL AND METHODS

Twelve adults (aged between 24 and 30 years) were recruited from among the postgraduate students of the University of Edinburgh. All participants were right handed by self-report, and free from neurological and visual impairments. Participants were asked to perform graphic copying tasks in a vision and in a no-vision condition. In the vision condition, the hand of the participants and the graphic copying sheet were visible. In the non-vision condition, a shelf (see Figure 9.1) was positioned above the copying space with a cloak covering the hand of the participants, in order to prevent the visual feedback of both graphic copying performance and hand movements.

The stimuli to be copied were similar in both conditions and consisted of complex multipart geometrical shapes, composed of the same sub-elements: two equilateral triangles (side of 16 mm), one octagon (60 × 4 mm), a square (20 × 20 mm), a circle with two diagonals (10 mm) and two lines (30 mm), arranged in different complex figures (see Figure 9.2 for an example). Each stimulus was printed in the centre of an A4 paper in a landscape orientation. In both conditions, the copying space was a separate sheet of an A4 paper in landscape orientation, with a black dot (2 × 2 mm) printed in the centre, presented in front of the participants in line with their body midline. Moreover, in the no-vision condition, the same sheet of paper was also presented on top of the shelf, in line with the copy sheet of paper, in order to provide participants with a frame of reference from the copying space.

Figure 9.1. Set up of the no-vision condition.

The striped lines indicate the shelf, which was placed above the hand of the participants.



In both vision and no-vision conditions, participants were asked to perform the graphic copying of the multipart shapes starting with the pen placed on top of the dot. The model was placed adjacent to the central sheet of paper[19] either to the right, to the top[20] or to the left of it.

Participants performed four blocks (two vision and two no-vision) of six trials each (see Figure 9.2). The vision/no-vision condition was blocked according to an

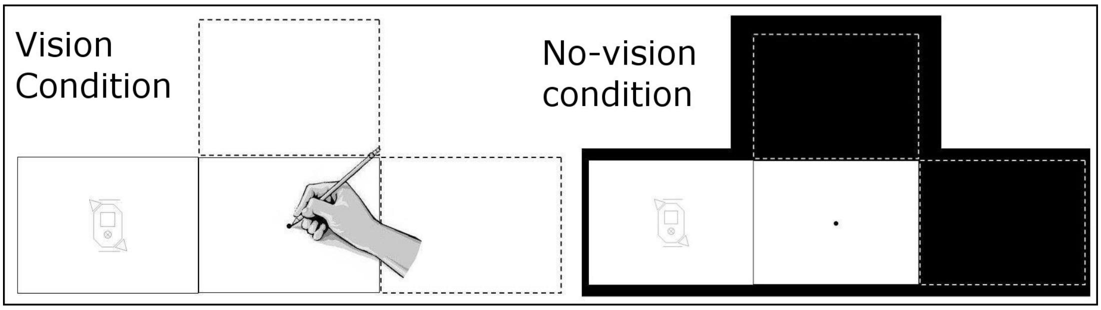
[19] The central sheet of paper refers to the copying sheet of paper in the vision condition and the sheet of paper placed on the top of the shelf in the no-vision condition.

[20] The term 'top' is used to refer to the presentation of the model in front of the participant adjacent to the sheet of paper to be copied on.

ABBA schedule, counterbalanced across participants. The position of the model (left, top, right) was manipulated within blocks according to an ABCCBA schedule, with condition order rotated among participants.

Figure 9.2. Illustration of the vision and no-vision conditions.

The dashed lines represent the other possible positions of the model.



Scoring procedure

Each graphic copying performance was scored considering the central starting point as the origin of a Cartesian coordinate system (see Figure 9.3). The left, right, top and bottom edges of the copy were measured in millimetres as deviations from the origin of the axes. The top and right deviations were positively signed and the bottom and left deviations were negatively signed. For both horizontal and vertical axes, the midpoint and the extent of the graphic copying were calculated.

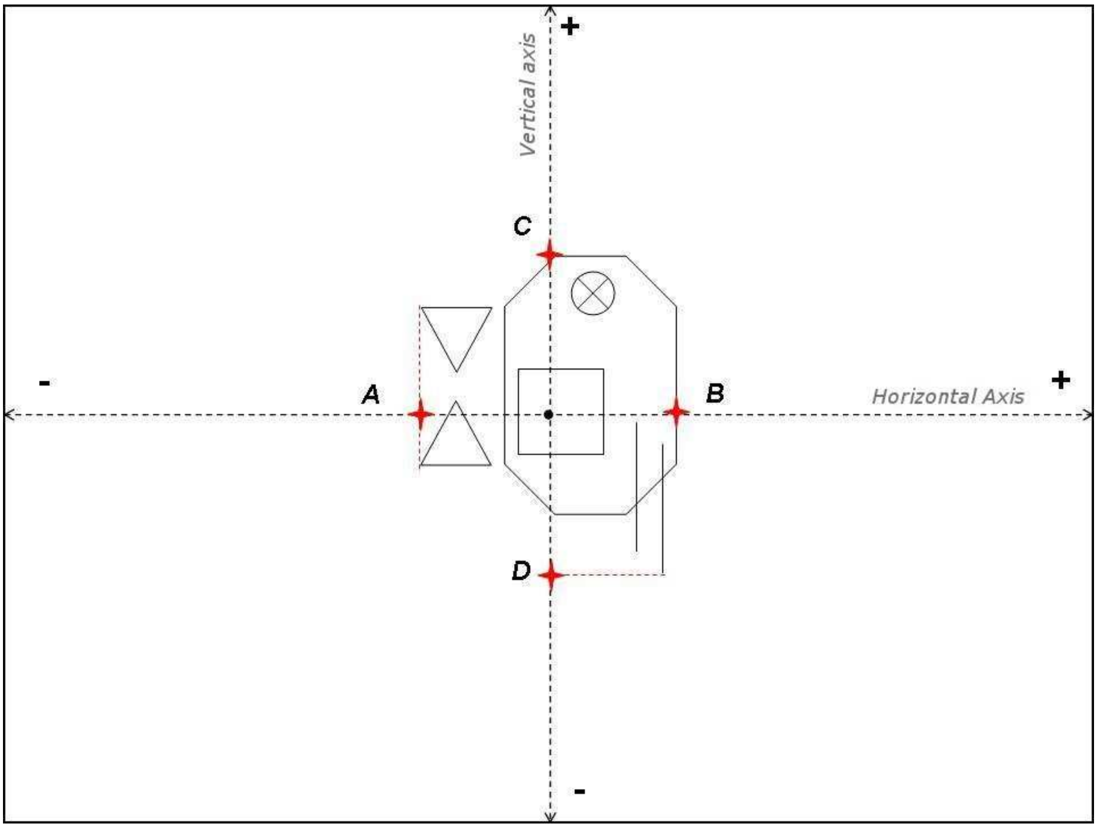
The horizontal midpoint was calculated as (A+B)/2, with A and B representing the left and right edges respectively (see Figure 9.3). In the same way, the vertical midpoint was calculated as (C+D)/2, with C and D representing the top and bottom edges of the drawing.

The horizontal and vertical extents were calculated as lengths of the lines between the edges of the graphic copy. The horizontal extent represented the distance between the left and right edges of the graphic copy and was calculated with the formula [B+(A*-1)]. The vertical extent represented the distance between the top and bottom edges of the graphic copy and was calculated with the formula [C+(D*-1)].

For the analysis of the vertical axis (midpoint and extent of the copy), the data of right and left conditions were averaged in order to obtain a measure of the copy performance when the model was presented in the horizontal axis. This measure was then analysed in contrast with the condition in which the model was presented in the vertical axis (at the top).

Figure 9.3. Illustration of the graphic copying scoring procedure.

The red crosses represent the left (A), right (B), top (C) and bottom (D) edges of the graphic coping measured as deviation from the central dot (origin of coordinate axes).



Therefore, four dependent variables were calculated. For the horizontal axis, the horizontal midpoint and horizontal extent; for the vertical axis, the vertical midpoint and vertical extent. The drawing bias toward the model position was assessed using the horizontal and vertical midpoints of the graphic, while the extent of the copy provided information about the size of the drawing.

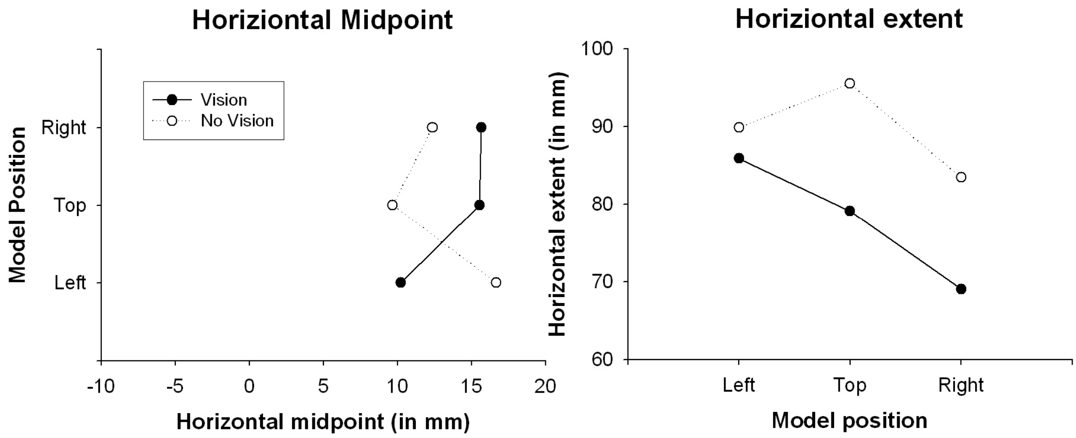
RESULTS

Horizontal axis

As shown in Figure 9.4, the horizontal midpoint of the graphic copy was always located on the right side of the sheet of paper. The horizontal midpoint was entered into a repeated-measures analysis of the variance (ANOVA) with degree of vision (vision, no-vision) and position (left, right and top) as the independent variables. The analysis showed a significant interaction between the degree of vision and position of the model, $F(2,22) = 11.63$, $p < .001$, but no main effects of degree of vision, $F(1,11) = .29$, $p = .59$, or model position, $F(2,22) = .61$, $p = .54$, were found.

This reliable interaction was further explored via follow up ANOVAs performed for each degree of vision separately, with an uncorrected alpha level. The analysis confirmed a significant effect of the model position for both vision, $F(2,22) = 6.40$, $p = .006$, and no-vision conditions, $F(2,22) = 6.44$, $p = .006$**.** For instance, in the vision condition, the horizontal midpoint was located more toward the left side of the paper, when the model was placed on the left rather than on the right, $t(11) = -2.56$, $p = .026$, and on the top positions, $t(11) = -2.93$, $p = .014$; while similar performances appeared when the model was placed on the right and on the top, $t(11) = .11$, $p = .91$. On the other hand, in the no-vision condition, the horizontal midpoint of the drawing deviated in the opposite direction from the model position. Therefore, the drawing was placed more toward the left side of the paper, when the model was placed in the top rather than the left position, $t(11) = 4.42$, $p = .001$. Similarly, with a trend toward significance, the drawing was placed more toward the left side of the paper when the model was placed on the right rather than on the left, $t(11) = -2.93$, $p = .059$. Instead, similar performance appeared in right and top conditions, $t(11) = 1.21$, $p = .25$.

Figure 9.4. Horizontal midpoint and extent in vision and no-vision conditions



The horizontal extent of graphic copying (see Figure 9.4) was larger in the no-vision than in the vision condition. A 2 × 3 (degree of vision × model position) repeated-measures ANOVA confirmed this evidence, showing a main effect of degree of vision, $F(1,11) = 6.35$, $p = .028$, and of model position, $F(2,22) = 16.81$, $p < .001$, as well as a significant interaction between degree of vision and the position of the model, $F(2,22) = 4.76$, $p = .019$

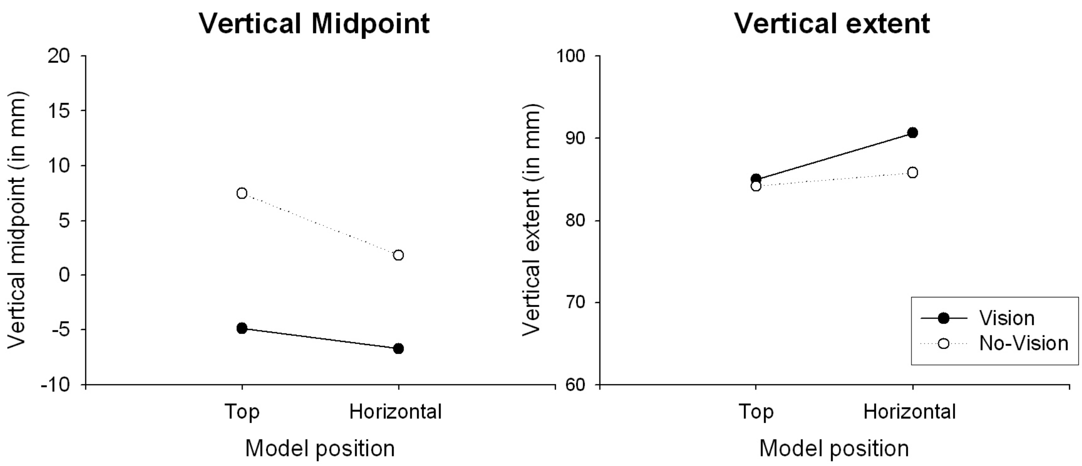
Follow up ANOVAs performed for each degree of vision separately, showed a significant effect of the model position for both vision condition, $F(2,22) = 24.50$, $p < .001$, and no-vision condition, $F(2,22) = 5.31$, $p = .024$, with an uncorrected alpha level. Post hoc tests conducted on the vision condition, with an uncorrected alpha level, showed that the extent of the drawing decreased progressively when the model was presented on the left and on the top, $t(11) = 3.11$, $p = .010$, and on the top and on the right, $t(11) = 3.99$, $p = .002$. Furthermore, the extent of the drawing was more pronounced in the left condition than in the right, $t(11) = 6.60$, $p < .001$. On the other hand, the extent of the drawing in the no-vision condition was larger when the model was presented on the top, compared to the left condition, $t(11) = -2.28$, $p = .04$, as well as compared to the right condition, $t(11) = -2.54$, $p = .02$, but it was similar in left and right conditions, $t(11) = 1.81$, $p = .09$.

To summarise the main results, a drawing bias toward the model position was observed in the vision condition, whereas a deviation of the drawing away from the model location appeared in the no-vision condition. Moreover, under the no-vision condition, the copy extent was higher compared with the vision condition.

Vertical axis

As shown in Figure 9.5, while in the vision condition, the vertical midpoint of the copy was slightly below the centre, in the non-vision condition it was slightly above centre. Moreover, in both conditions a bias toward the model position appeared. Therefore, graphic copying was performed more toward the top when the model was placed on the top rather than in the horizontal axis. A repeated-measure ANOVA by degree of vision (vision, no-vision) and model position (top and horizontal) confirmed this evidence. Main effects of the degree of vision, $F(1,11) = 12.50$, $p = .005$, and of the position of the model, $F(1,11) = 17.25$, $p = .002$, were found, but no significant interaction for degree of vision by model position was observed, $F(1,11) = 3.40$, $p = .092$.

Figure 9.5. Vertical midpoint and extent in vision and no-vision conditions



The vertical extent of graphic copying was similar in the vision and no-vision condition, but it was higher when the model was presented in the horizontal axis rather than on the top. A repeated-measures ANOVA confirmed this observation. No significant main effect of the degree of vision, $F(1,11) = .504$, $p = .49$, or a significant interaction between degree of vision and position of the model, $F(1,11) =$

1.58, p = .23, were found. On the other hand, a significant main effect of the position of the model, $F(1,11) = 5.08$, p = .045, was observed.

To summarise, a drawing bias toward the model position was observed in both vision and no-vision conditions. Moreover, this deviation of the drawing toward the model was larger in the no-vision condition than in the vision condition. The copy extent was similar in vision and no-vision condition, but it was higher when the model was placed in the horizontal plane rather than on the top.

DISCUSSION

The present study showed that a drawing bias toward the model position can be elicited in normal adults in a complex graphic copying drawing task. In the vision condition, in which participants were required to copy complex multipart shapes, the graphic copy was slightly misplaced toward the model position. This small but reliable model-directed bias was observed in both the vertical and the horizontal dimensions of the drawing. For instance, the analysis of the vertical axis showed that participants placed their drawing more toward the top of the page when the model was presented at the top rather than in the horizontal plane. The analysis of the horizontal axis showed that participants placed their copies more toward the left of the sheet when the model was presented on the left than on the right or top. These results are consistent with the attraction hypothesis of CIB (Kwon, 2002; Gainotti, 1972), which predicts that normal participants might show a default manual tendency toward the focus of attention. However, the interpretation of these results is weakened by the lack of significant difference between the right and top condition. There are no specific accounts to interpret this null finding, which compromise the definitive interpretation of these results.

Less consistent results were obtained assessing the effect of the degree of vision on this drawing bias. As described in the introduction to the present chapter, a further specification of the attraction hypothesis posits that attentional and/or executive resources might elicit the appearance of this default manual bias toward the focus of attention (Conson et al., 2009; Kwon et al., 2003; McIntosh et al., 2008), altering the ability of the patient to monitor manual performance with the consequent release of the tendency to act toward the attentional focus (see also Chapter 4). It was assumed that whereas in brain damaged patients, cognitive deficits trigger inadequate manual monitoring with the consequent appearance of CIB, in normal participants a similar behaviour might be mimicked, preventing normal monitoring of the manual performance. Therefore, it was predicted that in normal participants the magnitude of the model-directed bias would be higher under conditions in which monitoring of the manual performance was prevented by the removal of visual feedback. The results confirmed this prediction in the assessment of the vertical midpoint of the drawing; the drawing migration toward the model position was higher in the non-vision than in the vision condition. However, the pattern was not replicated for the horizontal midpoint. While a tendency to perform graphic copying toward the model appeared in the vision condition, an opposite pattern was found in the non-vision condition. In this last condition, the pattern was in fact reversed, so that the horizontal midpoint of the drawing was placed in the opposite direction from the model position.

It is not easy to offer a definitive account for these results, but a speculative interpretation can be proposed. This drawing bias away from the model position could be tentatively interpreted as an effect of head position, specific to the no-visual condition. Therefore, with left and right presentations of the model, participants were forced to turn their head toward the side in order to analyse the model. This position of the head could have induced a drawing deviation in the direction opposite from head rotation.

The present contralateral deviation of graphic copying from the model position in the no-vision condition can been explained as a similar sort of bias from the deviation observed in the subjective perception of the body midline, without the assistance of visual information regarding the position of the hand in the space (Jeannerod & Biguer, 1987; Jeannerod & Biguer, 1989). For instance, normal participants show a tendency to displace the subjective proprioceptive body midline in the direction opposite to a head rotation (Jeannerod & Biguer, 1987; Jeannerod & Biguer, 1989). Similar bias is also observed in tasks requiring estimates of the middle point of a rod. For instance, Chokron and Imbert (1993) showed that when young adults were asked to estimate the middle of a tactually-explored rod, aligned with the body midline, without visual feedback from the hand, their judgement was biased opposite to the direction of gaze. This bias, contralateral from the direction of the gaze, was observed when participants were required to use both tactile, and kinaesthetic information, or only kinaesthetic information in their judgements.

In support of this interpretation, Guerraz, Blouin, and Vercher (2003) observed a similar tendency in young adults performing a drawing task where vision of the hand movement and of the graphic performance was prevented. This experiment consisted of a preliminary tracing task in which participants were asked to follow the contour of geometrical shapes (square or diamond) with their index finger, presented on the centre of a board positioned vertically in front of them. In the experimental task, participants were asked to draw the same figures but with their eyes closed. The position of the subjects' head relative to the torso was manipulated, aligned or tilted right (25° toward the right shoulder) or left (25° toward the left shoulder). In the tilted head conditions, participants' drawings were rotated in the direction opposite from the head tilt.

Taken together, this evidence suggests that in the present experiment under the no-vision condition, participants' performance might have relied on proprioceptive information and direction of the gaze, reproducing a bias also observed in tasks requiring drawing with the head tilted or requiring the estimation of the body midline. This might have caused the misplacement of graphic copying toward the contralateral side from the head and gaze direction.

In the present experiment, the model was not presented at the bottom, and the top condition was meant to be used as a control condition. This is because the specific construction of the shelf did not allow the presentation of the model at the bottom position. A future experiment should be designed in order to compare graphic copying performance when the model is presented at the top and at the bottom in the vision and no-vision conditions with the specific instruction for the participants to keep their head in a constant position. These manipulations would aim to control the possible effects of the direction of the gaze, observed when stimuli are presented in the horizontal axis, and of the head position, when performing an action in the condition without vision of the hand. If these aspects influenced the performance in the no-vision condition, and can account for the present results, a graphic drawing bias toward the model position is expected to emerge in the no-vision condition, and to be of a larger magnitude in the no-vision rather than in the vision condition.

No specific predictions were formulated in relation to the graphic copying extent, although a simplistic interpretation would suggest that the extent of graphic copying would be different in the vision and no-vision condition, since in this last condition participants did not receive any feedback about their graphic performance. The result showed that the horizontal extent of graphic copying was higher in the no-vision condition than in the vision condition, while the vertical extent was constant in both. Therefore, the lack of visual feedback caused an increase of the horizontal extent, but it did not interfere with the vertical extent of the drawing. Interestingly, the model position was found to have an effect on the extent of the copy in the horizontal dimension, in particular in the vision condition, and in the vertical dimension.

To summarize, the present study showed that normal participants display a small drawing bias toward model position in complex graphic copying tasks, mimicking (on a smaller scale) the tendency to perform the graphic copy abnormally close to the model observed in brain damaged patients. However, this bias was not consistent across conditions, creating difficulties for a definitive interpretation of results, and therefore weakening the support obtained for the attraction hypothesis of CIB. Horizontal deviation pulled toward only the leftward model, and second it was not exacerbated by the no-vision condition; in fact, the pattern actually reversed to become a deviation away from the model on the left in horizontal dimension. Moreover, it is worth mentioning that this study simply explored the attraction hypothesis and did not test the compensation hypothesis. Therefore no conclusion can be drawn against this hypothesis. Future studies are needed to explore the role of manual monitoring insufficiency in the appearance of this bias toward the focus of attention and test the compensation hypothesis in normal participants.

CHAPTER 10
Eliciting a manual bias in a dual task condition in normal participants.

INTRODUCTION

In the previous chapter, the attraction hypothesis of CIB (Kwon, 2002; McIntosh et al., 2009; Gainotti, 1972) was explored in normal young adults. This hypothesis proposes that CIB is a primitive default tendency in which the active hand migrates toward the focus of attention (Lee et al., 2004). This tendency has been posited to be the effect of difficulties in monitoring the manual performance caused by attentional and/or executive deficits (Conson et al., 2009; Kwon et al., 2003). Therefore, the attraction hypothesis predicts that young adults may show a similar manual bias under conditions in which the demands on attention and executive resources is high. Moreover, it predicts that in normal participants this manual bias will be higher under conditions in which the opportunity of manual monitoring is reduced, mimicking the difficulties observed in patients with CIB. In order to explore this hypothesis, young adults were asked to perform graphic copying tasks in which the model position and the opportunity of manual monitoring were manipulated. The results showed that a small bias toward the model position was observed when normal participants were asked to perform these complex graphic copying tasks. However, this bias was not consistent across conditions, creating difficulties for a complete interpretation of results, and weakening the support obtained for the attraction hypothesis of CIB.

The present study has the same aim as the one reported in of Chapter 9. However, the possibility of eliciting a manual bias toward the focus of attention in normal participants has been explored using a different task rather than graphic copying. The rationale of this study is directly connected with the results observed in the single case study of a patient with AD (patient WS), who showed CIB in graphic copying and imitation of gestures (McIntosh et al., 2008; see also Chapter 4). This patient was presented with two dual tasks. In the first, a straight-line drawing task was combined with a letter-reading task; in the second, simple gesture production was combined with a letter-reading task. In each case, the patient showed a similar behaviour: the productions deviated markedly toward the location of the reading task, mimicking CIB. This evidence showed that the manual performance in both graphic and gestures tasks can be drawn toward the focus of visual attention. These results also suggested that the appearance of CIB in different tasks might be related to common mechanisms and that CIB is not specific to copying tasks, but a more general phenomenon, which can be elicited by any task requiring visual attention at one location and motor production at another. In a similar way, the present study aimed to explore the attraction hypothesis in normal participants in a task which did not require copying. Three experiments were designed to explore whether normal participants show a manual bias toward the focus of attention, mimicking the behaviour observed in patient WS. In all of the experiments a dual task paradigm was applied. The primary task was unrelated to the secondary task and consisted of a series of reciprocal pointing movements between two dots. The secondary task differed among the three experiments.

Experiment 1 explored if the increase of visual attention to a specific location during a reciprocal pointing task could influence the manual performance. Therefore, participants were required, in one condition, to perform a continuous series of reciprocal pointing movements, and in another condition, to perform this task in conjunction with visual monitoring for a target among a series of letters presented either to the right or left side. The attraction hypothesis predicts that the series of reciprocal pointing movements should deviate toward the location of the letters (focus of attention) in the dual task condition.

Experiment 2 explored the effect of the attentional load of the secondary task on the predicted manual bias toward the focus of visual attention. As stated before, a further specification of the attraction hypothesis of CIB suggests that this primitive behaviour is likely to appear under conditions of reduced executive and/or attentional resources. Therefore, the attentional load of the secondary task was manipulated. In low attentional load condition, young adults were asked to name all the letters appearing on one side of the screen; in the high attentional load condition, participants were required to switch between naming the letters and naming the colour of the letters. The attraction hypothesis predicts the increase of the manual bias in the high attentional load condition.

Finally, in Experiment 3, a similar experiment was carried out with older adults. The attraction hypothesis predicts that the default manual migration toward the focus of attention is likely to emerge with an increase in the difficulty of the visual task. As suggested in Chapter 4, this difficulty can derive not only from the characteristics of the task, but also from the cognitive resources of the participants. It is consequently possible to speculate that the general cognitive decline observed in normal aging would render older participants less able to perform the task, increasing the likelihood that CIB might emerge in this group of participants. As for the previous experiment, a larger migration toward the location of the letters was expected in the high, rather than in the low, attentional load condition.

It is worth mentioning that the study of influence of non-target visual stimuli on manual performance is not a novelty, and it is a recurrent topic in the attention and action literature. In particular, it is well established that when a distractor is present in conjunction with a target, the reaching movement toward the target is influenced by the presence of the distractor (Howard & Tipper, 1997; Meegan & Tipper, 1998; Tipper, Lortie, & Baylis, 1992; Welsh, Elliott, & Weeks, 1999). However, it is still debatable, which specific effect the distractor produces on the trajectory of movement toward the target. Although some studies suggest that when a distractor is presented, the movement veers away from the distractor (Howard & Tipper, 1997), other studies found opposite results, showing a tendency of the hand movement to move toward the distractor location (Welsh et al., 1999). This last tendency has been proposed to have its extreme manifestation in CIB in patients with AD (Chieffi, Ricci, & Carlomagno, 2001). Since in the present experiments, the targets of the movements were central dots (see Material and Methods), the letters, presented as stimuli of the secondary task, can be interpreted as distractors for reciprocal pointing movements. The results of the present study will be discussed, taking into account the attention and action literature.

MATERIAL AND METHODS

In all the experiments, stimuli were presented on a projection table (100 × 75 cm) in a horizontal position driven by a Pentium IV processor. Participants were standing centrally in front of the table, with their head immobilized in a chin rest, at a viewing distance of 70 cm. Hand movements were recorded by the Optotrak Certus system (Northern Digital Inc., Waterloo, Canada), which sampled, at 200 Hz, the 3D spatial position of an infrared emitting diode (IRED) attached to the nail of the right index finger.

All the experiments had a similar set up and represented a different variation of a similar dual task paradigm. The primary task was consistent across experiments and entailed a continuous series of reciprocal pointing movements with the right index finger between two black dots vertically[21] aligned in the centre of a grey screen (see Figure 10.1). In all the experiments, participants were instructed to start with the finger on top of the lower dot (1.5°) and perform first an upward movement, toward the upper dot (0.8°). In Experiment 1, a fixation cross (1.3°) was presented on the screen, but it was absent in Experiment 2 and 3.

At the end of each experiment, participant was asked to place the index finger on the top of the lower and upper dots, and the coordinates of the finger position recorded by the Optotrak Certus system. This calibration process was then used to refer the recorded movement coordinates for each participant to the target positions.

The requirement of the secondary task varied between experiments following specific aims. However, similar sets of stimuli were presented in all the experiments and consisted in letters of the alphabet (2.2°), presented on the right or on the left of the two dots. In all the experiments, participants were explicitly asked to prioritise the secondary task rather than the pointing movements.

The hand movement data were processed using customized Labview programs (National Instruments Inc.). For hand movements, the raw IRED position data was filtered by a dual-pass through a second-order low-pass Butter-worth filter with a cut-off frequency of 20 Hz. The tangential speed of the IRED was computed

[21] In this context, the term ‘horizontal’ and ‘vertical’ are used to refer to the long and short axes of the screen table. However, it should be noted that, the ‘vertical’ axis was actually oriented in depth, parallel to participants’ sagittal axis.

for each sample and this series was used to estimate movement onset and offset. Movement onset was estimated using the algorithm developed by Teasdale et al (1993; algorithm b), and movement offset was estimated using a simple threshold of 50 mm/s.

For the purpose of the study, the movement direction was not considered as a significant factor determining the results. Therefore, pointing movements in upward and downward direction were averaged together.

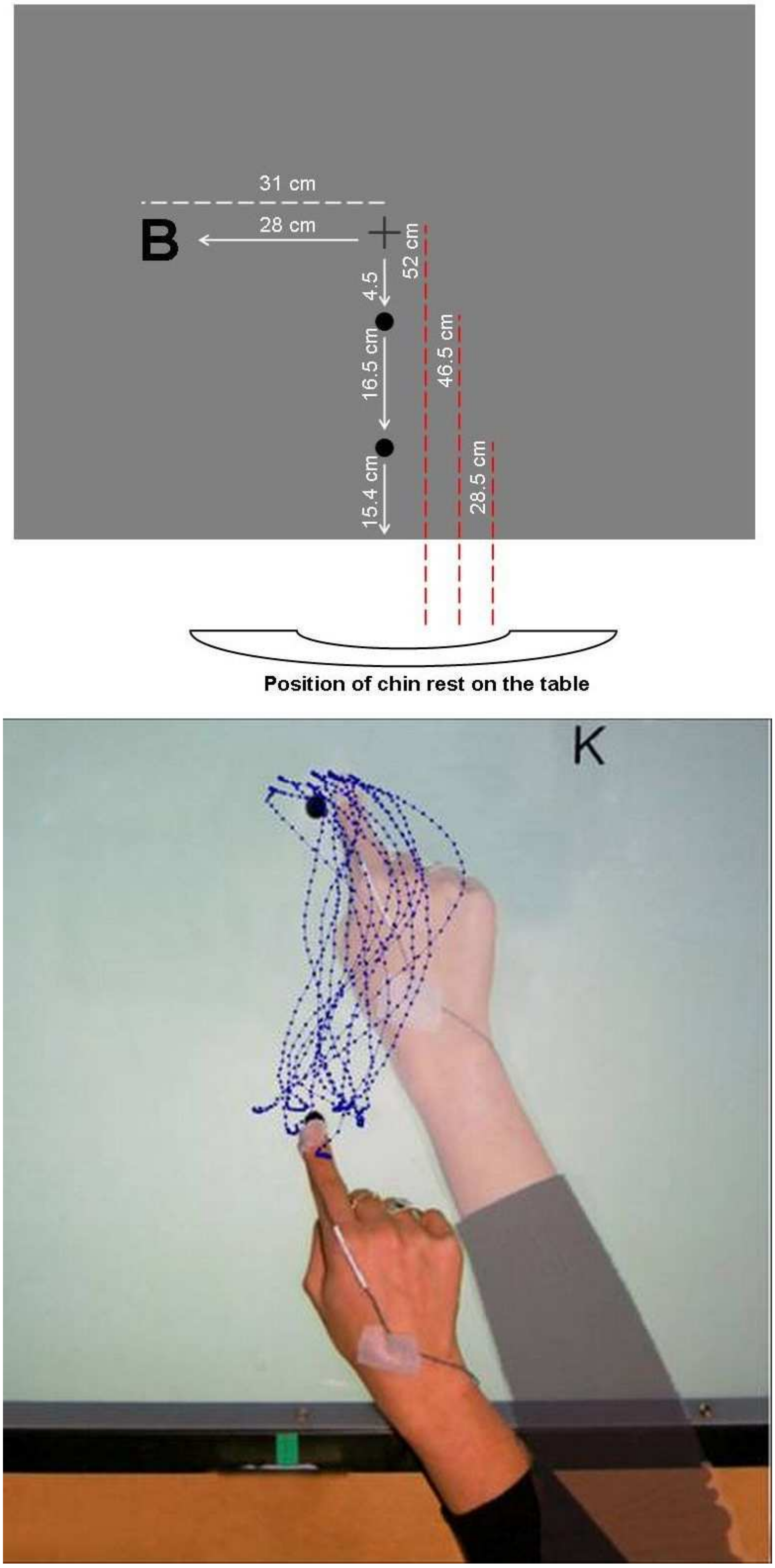
In all the experiments, the tendency to perform the series of reciprocal pointing movements toward the letters location was assessed by measuring the mean deviation in the horizontal axis from a straight vertical path between the two target positions.

Moreover, some kinematic measures were also calculated to assess whether the reciprocal pointing movements were performed in a similar way in the different experimental conditions. The kinematic variables taken into account were:

1. Movement time (ms): Time between onset and offset of the movement;
2. Normalized time to peak speed (%): The time between movement onset and the moment of peak speed normalised as a percentage of movement time. This variable gives information about the relative time of occurrence of the peak speed in the movement trajectory. It is an index of the acceleration period in relation to the deceleration period in the movement trajectory.

All the experiments were conducted in accordance with the 1964 Declaration of Helsinki, and with the approval of the Ethics Committee of the School of Philosophy, Psychology, and Language Sciences at the University of Edinburgh. All participants were right handed by self-report, and free from neurological and visual impairments.

Figure 10.1. General experimental set up similar in the three experiments (top panel) and representation of the hand reciprocal pointing movement trajectories veering toward the location of the letters during the dual task condition (bottom panel).



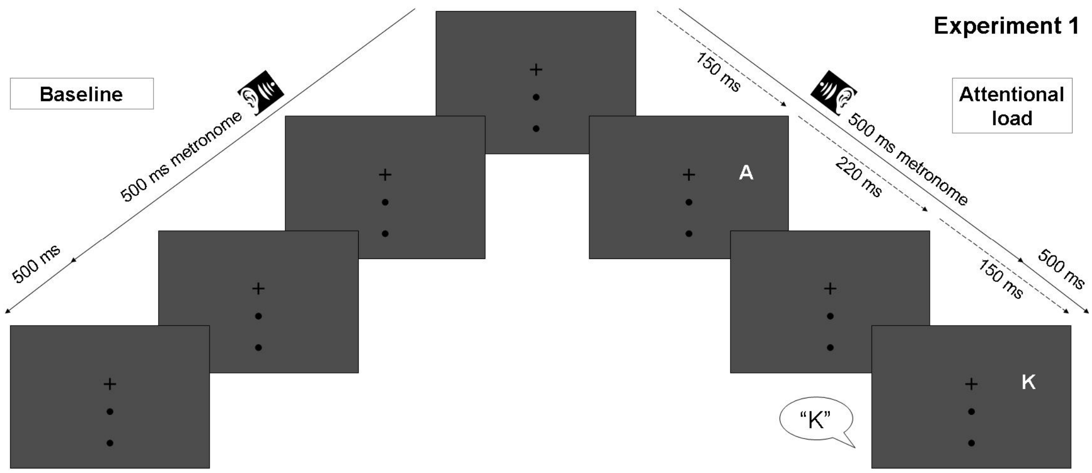
EXPERIMENT 1

This experiment aimed to assess the effect of visual attention on a continuous manual task. Sixteen young adults (aged between 18 and 24 years) were asked to perform a baseline and an attentional load condition (see Figure 10.2). In the *baseline condition*, participants were asked to perform a single task: a series of reciprocal pointing movements between two dots, while fixating a cross placed above the upper dot (see Figure 10.1). The pointing movements were paced by a regular tone (800 Hz) of 100 ms duration defining a 500 ms interval, from tone onset to tone onset, with an overall number of tones for each trial of 26. In the *attentional load condition*, participants were required to perform the reciprocal pointing movements but, at the same time, to monitor a series of white letters of the alphabet (from A to X) presented on the right (7 trials) or on the left (7 trials) of the fixation cross and to speak the letter "K" whenever it was presented in the series. This letter was presented 3 times in each trial, interspersed randomly among a series of 23 letters, for a total of 26 letters presented in each trial. As for the previous condition, participants were asked to synchronise the series of reciprocal pointing movements with the regular tone defining a 500 ms interval. As shown in Figure 10.2, the tone and the appearance of the letters were not time locked to each other; therefore, in some instances they occurred together, while in others, they did not. This methodology was applied in order to discourage participants from adopting a standardized procedure, for instance of checking the letters at a regular phase of the tapping movements, and to encourage continuous visual monitoring of the letters.

Each participant performed two blocks of 14 trials each, one block with the letters presented on the left and another block with the letters presented on the right. Therefore, the side of the letters was blocked between trials, starting with the letters presented on the left first, and then on the right, with the order of the blocks counterbalanced across participants. At the beginning of each block, participants were instructed that in half of the 14 trials, letters would appear in a specific location (on the left or on the right). Within blocks, baseline and attentional load conditions were presented in a random order (seven trials in each condition *per* block).

At the beginning of the experiment, three practice trials on the baseline were given to the participants, to familiarize them with the series of pointing movements. The examiner monitored performance for the entire duration of the experiment in order to make sure the instructions were followed. Therefore, if participants were not adjusting their movements to the metronome speed or if the number of movements performed was more or fewer than required, the examiner pointed at the correct execution of the task. However, the trial was not run again, and the data were used in the analysis.

Figure 10.2. Tasks design of Experiment 1

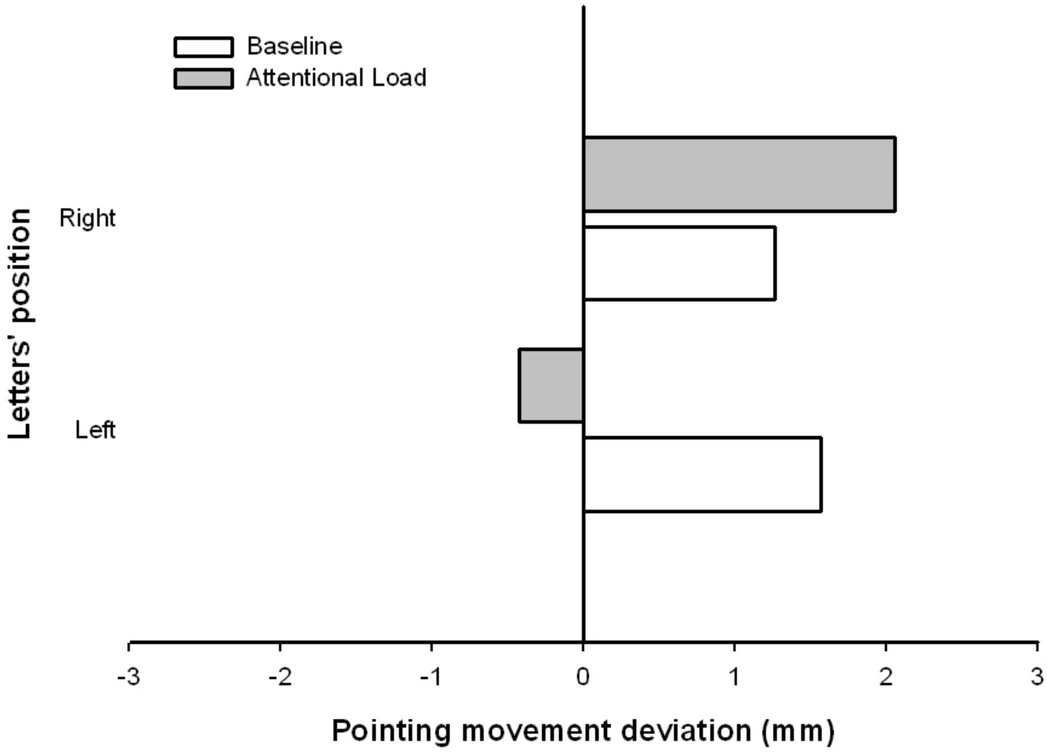


RESULTS EXPERIMENT 1

Mean horizontal deviation

The mean horizontal deviation of the movement in the baseline and attentional load condition is represented in Figure 10.3. A repeated-measures ANOVA, with attentional load (baseline, attentional load) and letter location (left, right) as the independent variables, showed a significant interaction between attentional load and position of the letters, $F(1,15) = 5.74$, $p = .03$. In the baseline condition, a similar rightward bias of the movement was observed regardless of the side of the letters, $t(15) = 1.048$, $p = .31$. This evidence was not surprising considering that participants performed the movements with their right hand. Instead, a trend toward significance was observed in the attentional load condition for the position of the letters, $t(15) = -2.053$, $p = .058$. In this condition, a small (1-2 mm) manual bias toward the side of the letters was observed during the dual task condition. The analysis did not show any main effect position of the letters, $F(1,15) = 2.72$, $p = .12$, or attentional load, $F(1,15) = 3.15$, $p = .09$.

Figure 10.3. Mean horizontal deviation of the series of reciprocal pointing movements in baseline and attentional load conditions by location of the letters.



Kinematic Analysis

The analysis of the movement time and of the normalized time to peak speed was conducted in order to assess if the kinematic aspect of the movements, such as the overall time and the normalized acceleration time of the movements, differed between conditions. The mean and *SD* of all the kinematic variables in each condition are reported in Table 10.1.

A 2 × 2 (attentional load × letter position) repeated-measures ANOVA on the overall movement time showed a significant main effect the attentional load, $F(1,15)$

= 18.42, p = .001, suggesting that participants took more time to perform the pointing movements in the no-attentional load condition. But, no significant main effect of the location of the letters, $F(1,15)$ = .151, p= .70, or significant interaction, $F(1,15)$ = .56, p= .46, were found for the movement time.

Table 10.1. Mean and *SD* of kinematic variables in all the conditions.

	No attentional Load		Attentional load	
	Left	**Right**	**Left**	**Right**
Movement time	417.62 (22.85)	417.89 (28.81)	404.14 (28.37)	406.76 (31.64)
Normalised time to peak speed	44.36 (4.81)	44.79 (4.67)	44.77 (5.49)	45.07 (4.81)

A repeated-measures ANOVA found that the normalized time to the peak speed did not vary with the attentional load, $F(1,15)$ = 1.07, p = .317, or with the letters positions, $F(1,15)$ = 1.04, p = .323. The interaction was also no significant, $F(1,15)$ = .086, p = .773.

DISCUSSION

The results of the present experiment suggested that normal participants show a small but not reliable manual bias toward the focus of attention in a dual task condition. Therefore, while a constant rightward bias of the series of reciprocal pointing movements was observed when the letters were not presented, the trajectory of the movement was influenced by the presentation of the stimuli. The series of reciprocal pointing movements veered toward the location of the letters while performing the dual task condition. Since the dual task condition influenced the trajectory of the movement, the attentional load of the secondary task was increased in Experiment 2, in order to explore the effect of increased attentional load in the appearance of the bias of the movement trajectory toward the location of the letters.

The analysis of the kinematic variables showed that the movement time was longer in the baseline condition than the attentional load condition. Therefore, it is possible to speculate that the longer movement time in the baseline condition may reflect the increased use of visual feedback in this condition. For instance, participants might have paid more attention to the movement in the baseline condition, using the visual feedback of the hand to a greater extent in this condition rather than in the attentional load condition (Rossetti et al., 1994).

Since the accuracy of the secondary task was not measured in this experiment, information about the participant's performance on the secondary task is unknown. It is impossible to know, therefore, if participants performed poorly in the letter naming task, showing a dual task decrement on this secondary task. This methodological lack was filled in the next experiment and the performance on the secondary task was taken into account in the analysis and discussion of the data.

A further shortcoming of this experiment, which has been corrected in the next two experiments, is that practice trials were given just for the baseline condition, but not for the attentional load condition. The practice trial for the baseline condition was given to allow young adults to be familiarized with the tone and to get use to performing the pointing movements in conjunction with the tone. This was considered naively as the difficult aspect of the task, while the difficulty level of the attentional load condition was underestimated.

EXPERIMENT 2

This experiment aimed to assess the effect of the attentional load of the secondary task in the magnitude of the manual bias toward the location of the letters. Eight participants (20-25 years old) were presented with the same background as in Experiment 1, with the only difference being the omission of the fixation cross.

As for Experiment 1, the primary task consisted of a series of reciprocal pointing movements to synchronise with a regular tone (800 Hz) of 100 ms duration defining a 1000 ms interval starting from the tone onset. The tone interval was longer than Experiment 1 and it was time locked with the appearance of the letters. This choice was made in order to reduce the possible confusion in performing the tasks. In this experiment (as well as in Experiment 3), the attentional load of the secondary task was manipulated and the tasks were more difficult than the previous one. It was reasoned that without time-locking the tone interval with the letter appearance, participants would have encountered a too difficult task. Therefore, participants were required to perform one pointing movement for each letter presented. The number of movements performed in each trial was 24 (12 performed in the upward direction and 12 in the downward direction).

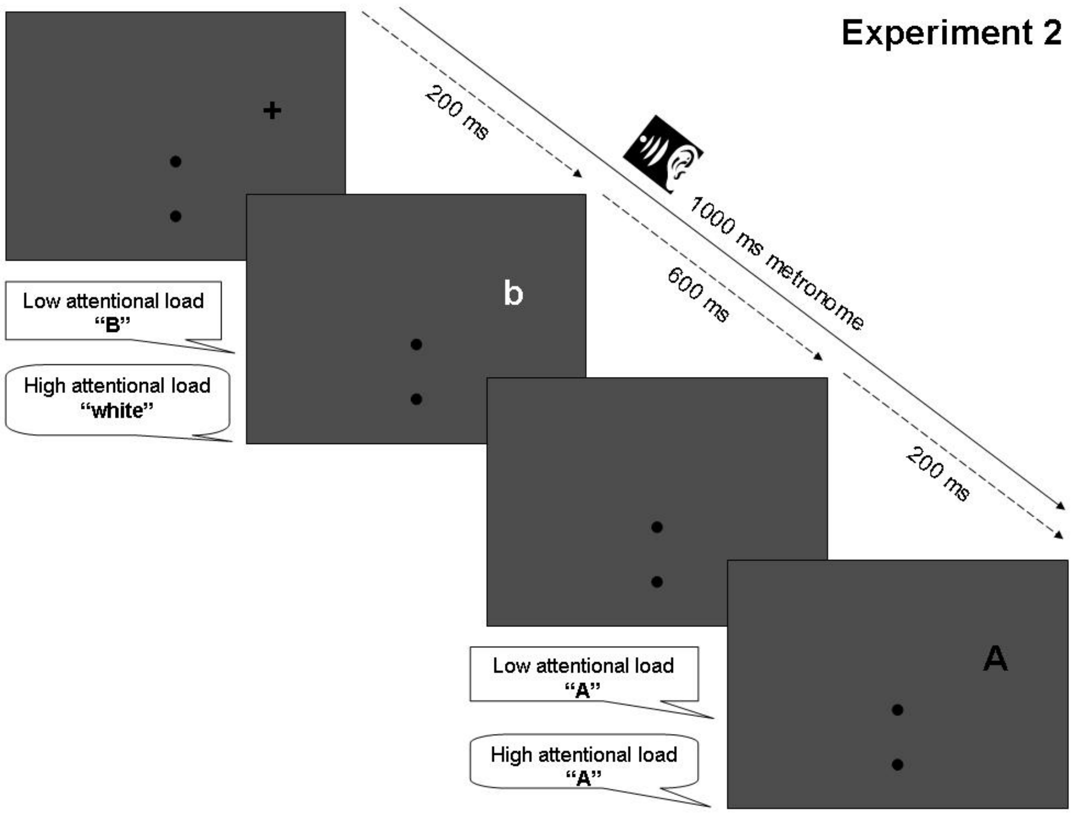
The attentional load of the secondary task was manipulated following a low and high condition (see Figure 10.4). In both conditions, the same stimuli were presented but the secondary task instruction was manipulated for low and high attentional load. The stimuli were series of letters of the alphabet (from A to Z) in upper or lower case presented in black or white colour on the right or on the left of the central dots. In the low attentional load condition, participants were asked to read aloud all the letters appearing on the screen. In the high attentional load condition, participants were required to perform a switching task: to name the letters presented in capital case and to name the colour of the letters presented in lower case.

Each participant performed four blocks, two in the low attentional load condition and two in high attentional load condition, of 8 trials each (32 trials overall). The attentional load of the secondary task was manipulated according to an ABAB schedule, with the low-attentional condition first and the block order alternated between participants. Instructions about the specific requirement of the secondary task were presented on the screen at the beginning of each block. Within each block, the letters were displayed on the right in four trials and on the left in four trials. At the beginning of each trial, a cross (4.48°) was presented on the right or on the left of the dots to indicate the location of the letters during the trial.

Each sequence of letters was composed of 24 letters from the alphabet (from A to Z), 12 presented in lower case and 12 in upper case, of which 6 were presented in black colour and 6 in white colour. The order of the letters was random, but blocked and alternated between participants, in order to ensure that participants performed the same number of attentional switches (10, 11, or 12 per trial) in the high attentional load condition.

Before each trial started, three regular tones (800 Hz) of 100 ms duration defining a 1000 ms interval starting from the tone onset were played in order to allow participants to familiarize with the metronome; then a higher tone (1000 Hz) of 100 ms duration was played to indicate the trial onset. Before the experiment started, two practice trials for each attentional load conditions were given to all the participants to familiarize with the task and, as for Experiment 1, the examiner monitored the participants' pointing movement during the experimental session. Trials were not run again if the pointing movements were not performed in perfect combination with the tone, and were used in the analysis. Finally, the examiner recorded in writing, the number of corrected (and uncorrected) answers in the naming task for each trial.

Figure 10.4. Task design of Experiment 2



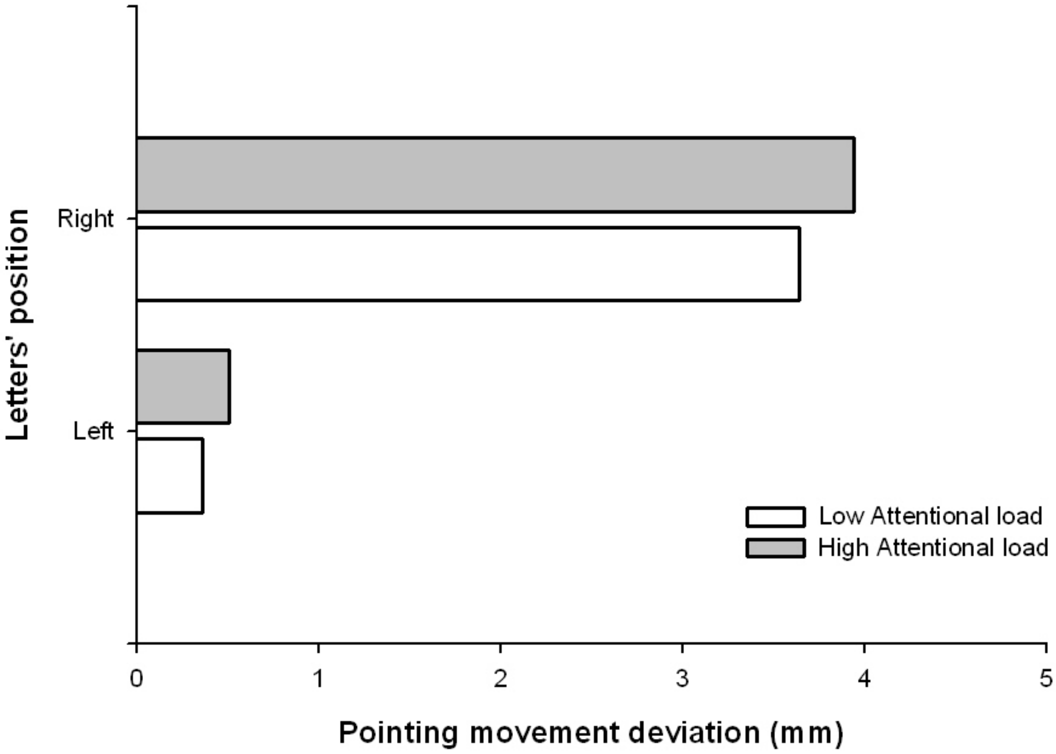
RESULTS EXPERIMENT 2

In order to assess the accuracy in the performance on the secondary task in the two experimental conditions, a paired t-test was conducted on the number of errors for each trial. The t-test found that significantly more errors were made in the high than in the low attention condition (mean 19.62, *SD 7.4*; vs., mean 1.50; *SD* 2), $t(7) = -7.24$, $p < .001$.

Mean horizontal deviation

As shown in Figure 10.5, the reciprocal pointing movements were performed on the right side of the central dots on both occasions when the letters were presented on the right or on the left. As in the previous experiment, this result was not unexpected as participants were performing the pointing movement task with their right hand. A repeated-measures ANOVA with attentional load (low, high) and letter location (left, right) as independent variables was carried out on the mean of the horizontal deviation of the movements to explore these observations. The analysis showed a main effect of the letter location, $F(1,7) = 16.74$, $p = .005$, confirming the manual attraction toward the location of the letters. However, there was no significant main effect of the attentional load, $F(1,7) = .081$, $p = .78$. Most importantly the interaction of attention load and letter location was not reliable, $F(1,7) = .052$, $p = .82$, so that this attraction was not found to be modulated by the attention load of the secondary task.

Figure 10.5. Mean horizontal deviation of the series of reciprocal pointing movements in high and low attentional load conditions by location of the letters.



Kinematic Analysis

The overall time spent to perform the movements, and the normalised time to peak speed is reported in Table 10.2. A 2 × 2 (attentional load × letter location) repeated-measures ANOVA was carried out on the manual kinematic variables. The analysis showed no significant main effects or interaction for normalised time to peak speed[22] and movement time[23]. Althought a trend toward a significant main effect of attentional load was observed in the movement time, $F(1,7) = 4.61$, $p = .069$, suggesting that the overall time spent to perform the series of reciprocal pointing movements was slightly longer in the low attentional load condition.

[22] No significant main effect of attention, $F(1,7) = .64$, $p = .808$, or location of the letters, $F(1,7) = .17$, $p = .68$, and no significant interaction, $F(1,7) = .04$, $p = .84$, was found

[23] No significant main effect of location of the letters, $F(1,7) = .89$, $p = .37$, and no significant interaction, $F(1,7) = 2.64$, $p = .14$, was found

Table 10.2. Mean and *SD* of each kinematic variable for all conditions.

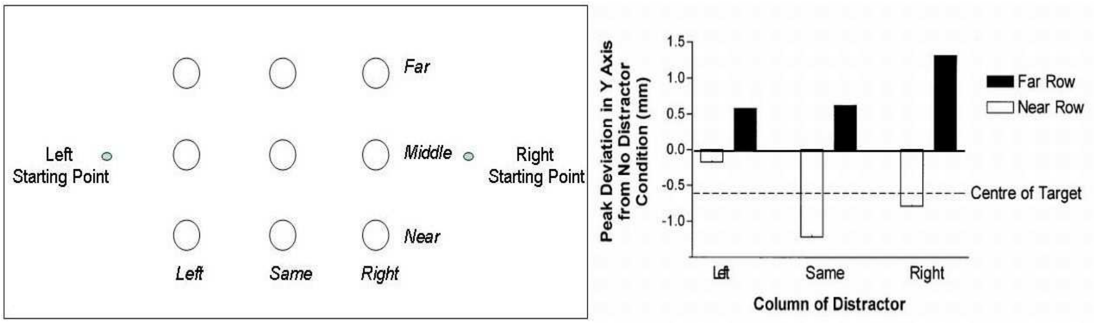
	Low attentional Load		High Attentional load	
	Left	Right	Left	Right
Movement time	641.26 (83.39)	648.57 (80.61)	621.10 (83.50)	621.66 (81.12)
Normalised time to peak speed	37.84 (4.92)	37.46 (5.34)	37.84 (5.19)	37.69 (4.97)

DISCUSSION

The results observed in Experiment 1 were replicated in the present experiment in both low and high attentional load condtions, confirming that young participants show a manual bias toward the location of the letters in a dual task condition. The manual bias toward the location of the letters observed in the present experiments might be of a similar nature as the hand deviation observed in experiments assessing the influence of a distractor in movement execution toward a target. In particular, Welsh et al. (1999) found that when a distractor was presented, the movement deviated toward the location of the distractor. Young participants were showen a 3 × 3 matrix of disks projected by a computer screen on a mirror (see Figure 10.10). When the trial started, one of the disks turned red (target) and participants were asked to perform a movement toward the target with the mouse on a tablet positioned below the mirror. The starting point of the movement was either on the right or on the left of the matrix and was fixed between blocks. In some trials a distractor (disks turned in green) was presented at the same time as the target, either the same column or in the right and left columns (see Figure 10.6). In order to assess the effect of the distractor display on the movement trajectory toward the target, the authors considered the movement performed in the middle row (the target was displayed in the middle row). As shown in Figure 10.6, the authors found that when the distractor was presented, the movements deviated toward the location of the target independently from the starting point. The authors interpreted this effect as relating to the parallel activation of the motor responses toward the target and distractor. Therefore, the race between these responses would create a combined movement trajectory intermediate between the target and the distractor location.

It is possible to speculate that the manual behaviour observed in Welsh et al. (1999) and in the present study might describe a common default manual behaviour, consisting of an automatic and primitive tendency to respond to a source of stimulation (Simon, 1990; Simon, Craft, & Webster, 1971). Therefore, when a relevant visual stimulus is presented, the attention is automatically driven toward the stimulus, with the consequent elicitation of motor programs toward the stimulus, which need to be inhibited for effective goal-directed behaviour.

Figure 10.6. From Welsh et al. (1999) study. Left panel representation of the experimental set up; right panel movement deviation toward the distractor corrected for control condition (movement toward the target when the distractor is not presented).



In the present experiment, the attentional load of the secondary task was also manipulated, with the expectation that the manual deviation toward the location of the letters would be greater with increased attentional load of the secondary task. Instead, the manual bias toward the location of the letters was equivalent in both low and high attentional load conditions. One possible explanation of these results is the performance trade off observed in a dual task condition (Temprado et al., 2001). In this dual task condition, participants might have prioritized the primary task over the secondary task in order to maintain an equivalent performance in reciprocal pointing movements between conditions. As a consequence, the performance on the secondary task would have been penalized, with the decrement of the performance in the secondary task in the high attentional load condition. In further support of this hypothesis, the accuracy of the secondary task significantly decreased in the high attentional load condition. Taken together, these results suggest that the modulation of the attentional load had an effect on the secondary task performance, but not on the primary pointing movement task.

Another aspect to be taken into account is that the manipulation of the attention load of the secondary task was based on the addition of an attention switching demand (between letter and colour naming). The rationale of this manipulation derived from previous evidence of the involvement of this attention demanding ability in the appearance of CIB in children (see Chapter 6). The lack of modulation of manual bias between the attentional load conditions might reflect the importance of other attentional subcomponents, such as selective or sustained attention, which have been neglected in the present experiment. These other forms of attention could play an important role in the genesis of this bias in normal participants and further experiments could be designed to explore the role of these attentional resources.

Finally, in the present experiment the focus of fixation was constant in both conditions (on the letters) and overlapped the focus of attention. The manual bias observed could be explained as a migration toward the focus of fixation rather than the attention-demanding visual stimuli. This hypothesis is speculative and future experiments should investigate the role of attention and fixation in the appearance of this manual bias, spatially dissociating the two. Therefore, participants could be presented with a similar dual task experiment in which the primary task is the series of reciprocal pointing movements, but the location of attention and fixation are factorially combined. Participants could be asked to fixate a cross presented at one of two locations (right or left of the midline of the projector table); while some colored squares are presented at the other location. Participants would be required to keep the fixation on the cross, but to pay attention and monitor the other location to name the color of the squares. This experiment would help to distinguish between the role of focus of attention and fixation in CIB. Therefore, the attraction hypothesis would predict that participants would show a manual bias toward the location of the squares (focus of attention but not fixation), replicating the results of the proposed experiment. On the contrary, if a manual bias is not replicated in this experiment, it could be concluded that the manual bias observed is toward the focus of fixation.

EXPERIMENT 3

As previously stated, this experiment tested the hypothesis that a larger manual bias toward the focus of attention is likely to appear in normal aging. The decrease of cognitive resources could hamper the ability of participants to perform the task and increase the likelihood of the appearance of a manual bias toward the location of the letters. Therefore, ten older adults (63-71 years old, mean age 67.8; mean education 14.4 years), five males and five females, were recruited from the volunteer panel of the University of Edinburgh and were presented with the same experimental set up as Experiment 2. The only change was in the stimuli and requirements of the attentional load conditions.

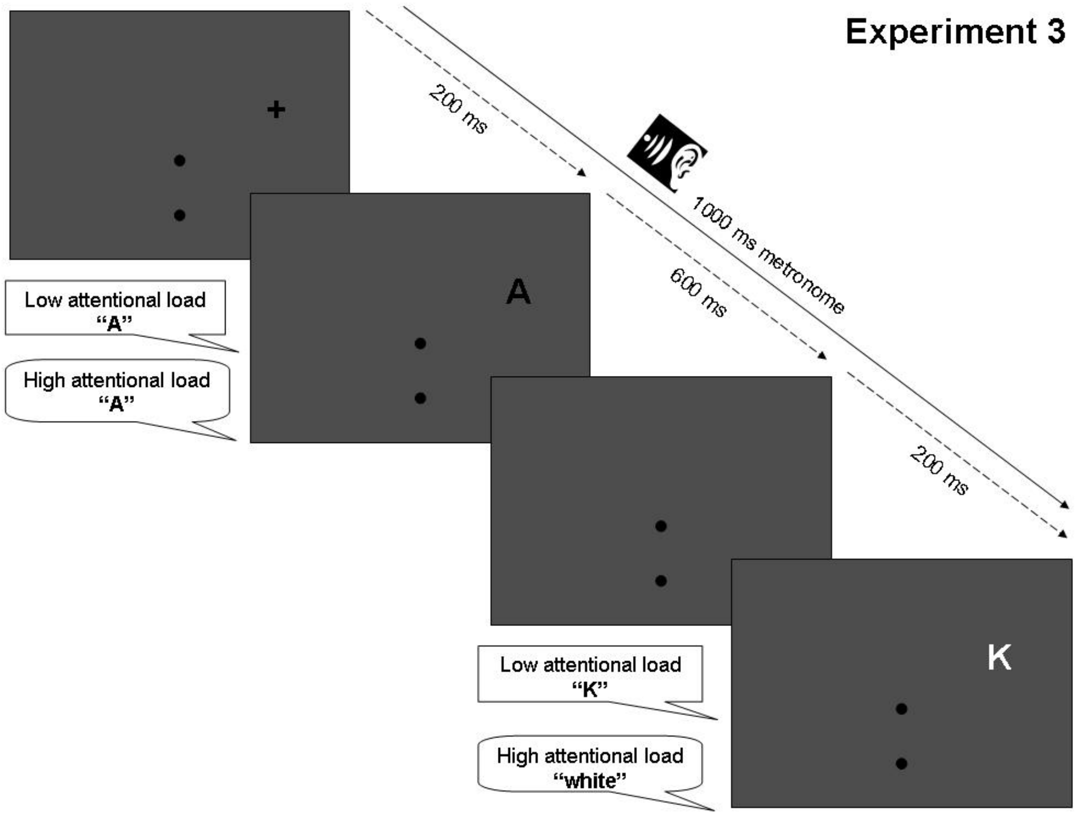
As for Experiment 2, the stimuli consisted of black and white letters of the alphabet (A to Z), but they were presented in upper case only. Also like in the previous experiment, in the *low attentional load condition*, participants were required to perform a series of reciprocal pointing movements synchronized with a metronome (1000 ms) and to name the series of letters presented on the right or on the left of the central dots. The *high attention load condition* was slightly modified from the previous experiment in order to adapt the task for older adults, decreasing the task difficulty (see Figure 10.7). Therefore, in conjunction with the primary pointing movement task, participants were required to perform a switching attention task: to perform a letter naming task (as in the previous condition), but switching to name the colour of a single stimulus (the letter K).

The experimental design was the same as Experiment 2. Each participant performed 4 blocks of 8 trials (16 low and16 high attention). The attentional load was manipulated according to an ABAB schedule, with the initial block counterbalanced across patients.

Within each block, the letters were presented on the right in four trials, and on the left in four other trials. At the beginning of each trial, a cross (4.48°) was presented on the right or on the left of the dots to indicate the location of the letters during the trial. Twenty four letters (from A to Z) were presented in each trial, ten of which were the letter *K* (5 white and 5 black) randomly distributed in the sequence of letters. The sequence of the letters was fixed in a pseudo random order and alternated between participants in order to ensure that participants performed the same number of attentional switches (10-17 for each trial) in the high attentional load condition

As in the previous experiment, at the beginning of each trial, three regular tones (800 Hz) of 100 ms duration defining a1000 ms interval starting from the tone onset were played. Then a higher tone (1000 Hz) of 100 ms duration was played to indicate the trial onset. Before the experiment started, two practice trials for each attentional load condition were given to participants to familiarize them with the task. As for the previous experiments, the examiner monitored the participants' pointing movement performance during the experimental session, and pointed at the correct execution of the task. The trials where the pointing movements were not precisely executed in conjunction with the tone were not run again and the data were used in the analysis.

Figure 10.7. Tasks design of Experiment 3



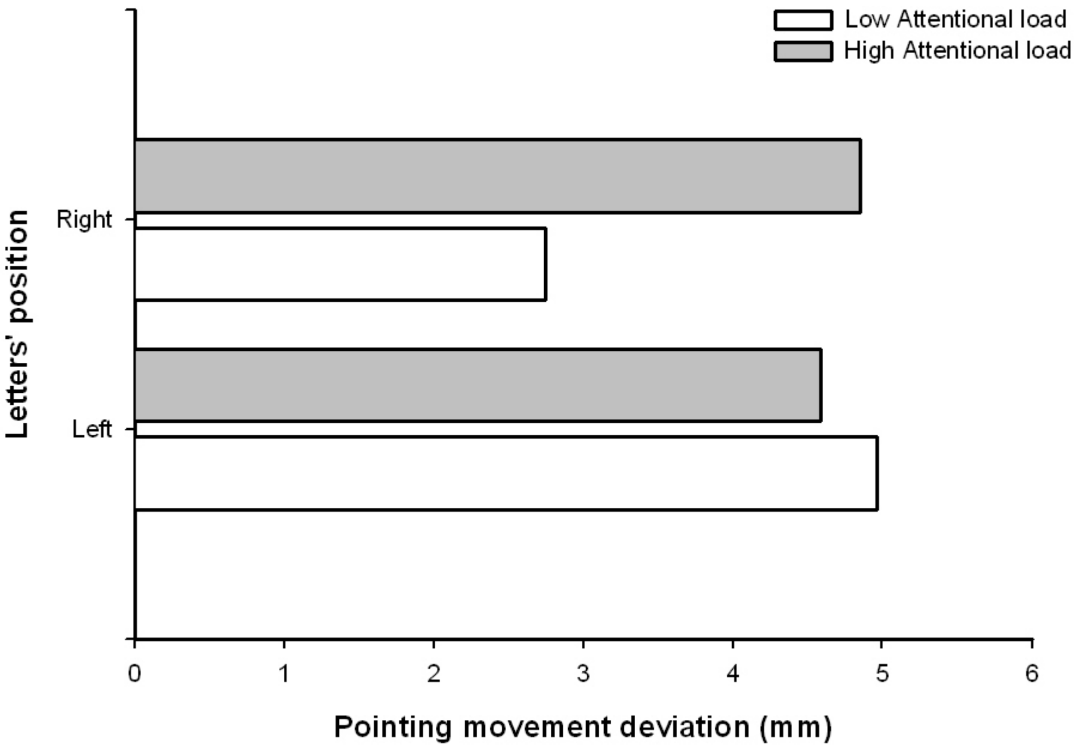
RESULTS EXPERIMENT 3

A paired t-test did not find a significant difference in the high than in the low attention condition (mean 7.88, *SD* 4.7 ; vs., mean 4.71, *SD* 7.8), $t(9) = -1.19$, $p = .26$. The secondary task was performed with the same degree of accuracy in both attentional load conditions.

Mean horizontal deviation

A 2 × 2 (attentional load × location of the letters) repeated-measures ANOVA was carried out on the mean of the horizontal coordinate of the pointing movements. In contrast to the previous experiments, the analysis did not show a reliable effect of the letter location, $F(1,9) = .80$, $p = .39$. Therefore, as shown in Figure 10.8, older participants performed the series of reciprocal pointing movements toward the right half of the table to the same extent irrespective of the location of the letters. The analysis did not show a significant main effect of attentional load, $F(1,9) = 1.28$, $p = .28$. The only significant result was the interaction between attentional load and location of the letters, $F(1,9) = 7.27$, $p = .025$. As shown in Figure 10.8, whereas in the high attentional load condition, a rightward bias was constant; in the low attentional load condition, a small manual deviation in the opposite direction from the location of the letters was observed. Post hoc tests did not show any significant result. However, a trend toward significance in the comparison between high and low attentional load conditions when the letters were presented on the right, $t(9) = -2.16$, $p = .058$.

Figure 10.8. Mean horizontal deviation of the series of reciprocal pointing movements in high and low attentional load conditions by letter's position.



Kinematic Analysis

Mean and *SD* of the manual kinematics for all the conditions are reported in Table 10.3. As shown in Table 10.3, the overall time spent to produce the series of reciprocal pointing movements and the normalized time to peak speed were similar in all the conditions. A repeated-measure ANOVA by attentional load (low, high) and location of the letters (left, right) confirmed this evidence, showing no significant main effects or interaction for normalised time to peak speed[24] and movement time[25].

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[24] No significant main effect of attention, $F(1,9) = .61$, $p = .89$, or location of the letters, $F(1,9) = 1.60$, $p = .23$, and no significant interaction, $F(1,9) = 2.89$, $p = .12$, was found

[25] No significant main effect of attention, $F(1,9) = 3.46$, $p = .09$, and location of the letters, $F(1,9) = .45$, $p = .51$, and no significant interaction, $F(1,7) = 3.30$, $p = .10$, was found

Table 10.3. Mean and *SD* of each kinematic variable for all conditions.

	Low attentional Load		High Attentional load	
	Left	**Right**	**Left**	**Right**
Movement time	605.40 (91.55)	615.55 (97.81)	609.20 (102.13)	608.15 (103.97)
Normalised time to peak speed	37.41 (5.13)	35.88 (3.31)	37.53 (5.00)	37.69 (4.14)

DISCUSSION

This experiment aimed to assess the effect of aging in manual bias toward the focus of attention, with the expectation that elderly participants would show a manual bias toward the location of the letters, replicating the results of Experiment 2 with young adults. Surprisingly, the results did not meet these expectations. The results of Experiment 2 were not replicated, but a pointing movement bias in the opposite direction from the location of the letters was observed in the low attentional load condition; while a consistent rightward bias was observed in the high attentional load condition.

Another prediction of the present experiment was that a higher magnitude of manual bias toward the focus of attention would appear in older, rather than younger participants. Therefore, the next step of this experiment would have been to include a control group of young adults and to compare their performance with the older group on the same task. Since the results of Experiment 2 were not replicated, and older adults showed a manual bias in the opposite direction from the location of the letters, this experiment was not extended to include young adults.

How can the apparently conflicting findings of these experiments be reconciled? It is not easy to provide a definitive account for these results, but some speculative points can be raised; in particular by considering these results in relation to the attention and action literature. Howard and Tipper (1997) observed that when a visual cue (distractor) is presented, the hand movement toward a possible target deviated away from the visual cue. The authors interpreted this effect as a result of the inhibition of the automatic response toward the distractor. In a reaching task toward a target, the presence of the distractor is postulated to be coded as an action based representation. A covert response toward the distractor is prepared in conjunction with the action toward the target, and the two responses are processed in parallel. However, since the task requires that an action is performed toward the target, the representation of alternative action toward the distractor is inhibited in order to correctly perform the task (Tipper 1985). As Welsh et al. (1999) proposed, the race between the two responses (toward the target and the distractor) might produce the deviation of the hand toward the distractor. It has also been proposed that in the condition in which the participants perceive that their hand movement could obstruct the visibility of the dictractor, a tendency of the hand movement to veer away from the distractor location is observed (Tresilian, 1998)

Following this view, it is possible to speculate that in the present dual tasks, in conjunction with the manual response prepared toward the dots (target of the reciprocal pointing movements), a response toward the location of the letters (distractor of the primary task) was also prepared. In younger participants, the response toward the distractor was not so prominent and did not obstruct the visibility of the letters. Therefore, a tendency toward the location of the letters was observed. On the contrary, in older participants the attraction toward the location of the letters might have been so strong as to generate a response toward the location of the letters. This might have had a high cost on the primary task, obstructing the letters and compromising the pointing movement performance. In order to prevent this *obstruction effect*, a covert response away from the location of the letters might have been generated. As previously stated, this interpretation is speculative and further studies should be conducted. A possible way to test this last hypothesis might be to present older participants with the same experiment under two different conditions: with and without the hand being visible. If this hypothesis is correct, in the no-vision condition, older participants would show a deviation toward the location of the letters, since they would not be affected by the obstruction effect of the hand movement. Another speculative interpretation of these results is that the present group of older adults was recruited from the volunteer panel of the University of Edinburgh. This panel is composed of people who are willing to participate in experiments conducted in psychology, and are therefore used to the experimental setting. For this reason, their performance might be biased from their implicit interpretations of the examiner’s expectation and of the demand characteristic. Older adults might have been more careful in their performance than young adults performing the task, in order to meet their interpretation of the experiment's purpose. Although the instruction was to keep the gaze on the letters without paying attention to the movements, this group of participants might have instead monitored the manual performance more consistently. During the experimental session, most of these participants were often paying attention to the hand movement and shifting their gaze between the hand movement and the letters, and the examiner had to repeat the instructions several times between trials. The monitoring of the manual performance might have therefore prevented or even counteracted the appearance of this default behaviour. However, this explanation is speculative and since the eye movements were not controlled during the task, there is no empirical evidence supporting this hypothesis.

Moreover, a further limitation of this study is that participants were not presented with a general cognitive assessment. Therefore, the assumption of the cognitive decline in relation to the age was not directly tested but was an implicit assumption. It is possible that the general level of cognitive abilities, in particular attention and executive functions, were not impaired in this group. The present sample might not be specifically affected by cognitive aging and therefore not representative of the elderly population in this respect. Furthermore, older adults volunteering for the research panel might not be representative of the elderly populations in general, since they tend to be well-educated, intelligent, highly engaged, and active. However, it is important to realize that the possible integrity of the cognitive functions among these participants might explain the replication of the results of Experiment 2 in the present group of participants, but it does not account for the appearance of a manual bias in the opposite direction from the location of the letters.

CONCLUSION

These studies demonstrated that normal participants can exhibit a small manual bias toward the focus of attention when performing a simple dual task condition (Experiments 1 and 2), subtly mimicking the manual approach behaviour of patients with CIB (see Chapter 4). However, the manual bias observed in the present study was not influenced in the manner predicted by the attention load of the secondary task (Experiment 2) or by aging (Experiment 3). Indeed, older adults showed an opposite trend from young adult: in the low attentional load condition a manual bias in the opposite direction from the location of the letters was observed.

However, the present study did not assess if the bias observed in the present experiments is the same phenomenon observed in the previous sections. Morever, the present results might be considered as consistent with the attraction hypothesis of CIB, but not as evidence against the compensation hypothesis, which was not tested in the present study.

Although these studies suggest the existence of a default manual bias toward the focus of attention in normal participants, the inconsistency of results across experiments need to be further explored. There is evidence that strategic responses to default veering, such as inhibition, may be quite unpredictable. This is a very difficult area in which to make confident predictions, as testified by the inconsistent results throughout this section.

CHAPTER 11

SUMMARY

The present thesis developed within the broader framework of CA. As described in Chapter 1, CA is a complex and ambiguous diagnostic category, which incorporates a variety of impairments observed in different constructional tasks. In line with recent trends in the study of this syndrome, the present thesis took a more specific approach to the study of CA, isolating one constructional symptom, CIB, and examining its characteristics and origins in detail.

In the present thesis, the study of this phenomenon has been undertaken by three main methdological routes: survey studies, experimental studies, and modelling of CIB. As summarized in Table 11.1, both survey and experimental studies were carried out with patients with dementia and pre-school children using analogous methods. This particular structure allowed not only the assessment of the characteristics of CIB, but also an evaluation whether superficial similarities reflected a common cognitive origin of CIB in development and dementia. The results of these survey studies confirmed the previously noted mirror pattern of CIB frequencies in development and dementia, such as that the frequency of CIB increases with dementia severity, whereas it decreases with the developmental course in children. More importantly the survey studies provided converging evidence for a primary role of attention deficits in the appearance of CIB. Although the results obtained with pre-school children pointed toward the specific involvement of attention switching problems in the appearance of CIB, the retrospective nature of the dataset of patients with AD did not allow a test for this specific ability, and therefore this association has not yet been evaluated in patients with dementia.

In a similar way, experimental studies, which tested between two competing hypotheses of CIB using a dual task paradigm, yielded closely comparable results. In these dual task experiments, a patient with AD and pre-school children showed equivalent behaviours: the primary manual performance was executed toward the target-stimuli of the secondary task. Moreover, this behaviour was elicited in the patient with AD, not only in the drawing domain, but also in gesture production. These lines of evidence not only supported the attraction hypothesis, but

strengthened the link between the appearance of CIB in dementia and development, and across graphic and gestural domains. From this set of studies, a major conclusion of the present thesis was drawn: CIB is a general default behaviour in which manual performance is automatically driven toward the focus of attention. To date, the results obtained with this patient with AD have not been replicated in a larger group of patients. As described in Chapter 5, the attempt to recruit a group of patients with AD and CIB was not successful, because of several practical limitations. Future studies will be required to test the possibility of generalizing the conclusions drawn from the single case study to larger groups of patients with AD.

The last set of studies aimed to model CIB in normal adult participants, using complex graphic copying tasks and dual task conditions, based on a similar rationale to that used in the experimental studies of patients with AD and children. This goal was arguably achieved, in that a small manual bias toward the focus of attention was observed in normal participants using both methodologies. However, the inconsistency of results within and between experiments leaves open the question of whether or not this phenomenon might be reliably elicited in normal participants. Most importantly, the results observed in the series of dual task experiments (Chapter 10) led back to a phenomenon commonly recognized in the attention and action literature. When normal young adults are asked to perform a movement toward a target in the presence of a distractor stimulus, the distractor influences the movement trajectory, causing a deviation of the movement trajectories either toward (Welsh et al., 1999) or away (Tipper et al., 1992) from the distractor. In a similar way, the experiments reported in Chapter 10 showed that the movement trajectory was influenced by the location of the letters, generating a bias in the pointing movement trajectory either toward (Experiment 1 and 2) or away (Experiment 3) from the distractor location. As an explanation of these results, it has been proposed that the natural tendency to perform an action toward attention-demanding stimuli may be actively inhibited in normal participants, producing somewhat variable and unpredictable spatial patterns of distractor influence. Future studies need to be carried out to explore this hypothesis, but the similarities between these results and the prior literature on distractor effects reinforce the idea that the attraction of manual trajectory toward the distractor location may be a universal default tendency in normal adults (Chieffi et al., 2001).

Table 11.1. Summary of the studies described in the present thesis

	Sample	Tasks and Scoring procedure for CIB	Further tasks	Results	Conclusion
			Survey studies		
Chapter 3	Patients with dementia AD (n = 797 - follow up n = 132) FTD (n = 56)	Graphic copying (square, diamond, multipart shape) Qualitative (near and overlap CIB)	Neuropsychological assessment (including memory, attention and visuospatial tasks)	1) CIB frequency increases in copying more complex shapes (in AD but not in FTD) 2) CIB frequency increases in severe dementia (in AD and FTD) 3) Similar frequency CIB in AD and FTD 4) Near-type CIB is predicted by attentional deficits; while overlap CIB is predicted by attentional and visuospatial deficits	1) Progressive pattern of CIB and CA with severity of AD 2) CIB is as common in AD as in FTD 3) Different cognitive origins of CIB in AD and FTD 4) The two CIB types do not simply lie on a continuum of severity but also reflect different involvement of attention and visuospatial factors
Chapter 6	Preschool Children (*n* = 41)	Graphic copying (nine geometrical shapes and Luria's figure) Qualitative (near and overlap CIB)	Tasks for the assessment of memory, attention and visuospatial abilities	1) CIB frequency increases in copying more complex shapes 2) CIB frequency decrease with the age of the children using Luria's figure copying task 3) CIB is predicted by performances in attentional tasks and in particular by the attentional switching task.	1) CIB is a normal phenomenon in development 2) Importance of Luria's figure in assessing CIB 3) Attentional immaturity as cognitive origin of CIB in development.

Chapter	Sample	Tasks and Scoring procedure for CIB	Further tasks	Results	Conclusion
			Experimental studies		
Chapter 4 (and 5)	Patient(s) with AD	• Graphic copying (nine geometrical shapes) • Qualitative (touching/overlapping) and quantitative (average of vertical distribution and slope)	Gesture and graphic copying: • Preliminary copying task • Dual task condition (straight line drawing/letters naming)	1) CIB increases with task complexity 2) CIB appeared in the dual task condition, in which the secondary task is unrelated to the primary task in both gesture and drawing. 3) This bias was not modulated by the density of the stimuli presented	1) Average of the vertical distribution as better measure of CIB 2) Importance of varying the model position 3) CIB is not specific to copying tasks 4) Support for attraction versus compensation hypothesis
Chapter 7	Preschool Children (n = 15)	• Graphic copying (nine geometrical shapes) • Qualitative (near/partial overlap/ wholly overlap) and quantitative (average of vertical distribution)	Graphic copying: • Preliminary graphic copying task • Dual task condition (straight line drawing/letters naming)	1) CIB increases with task complexity 2) CIB appeared in the dual task condition, in which the secondary task is unrelated to the primary task. 3) CIB observed in the dual task correlated with CIB in graphic copying. 4) This bias was not modulated by the density of the stimuli presented	1) Importance of varying the model position 2) CIB is not specific to copying tasks 3) Support for attraction versus compensation hypothesis 4) The dual task condition mimics CIB in graphic copying

Chapter	Sample	Tasks and Scoring procedure for CIB	Further tasks	Results	Conclusion
Experimental studies					
Chapter 8	Preschool Children (*n* = 16)		4 Dual task experiments with manipulation of: • Perceptual salience • Attention switching • Perceptual salience/ Response inhibition • Memory	1) CIB appeared in all the dual task experiments 2) The magnitude of CIB varied in the perceptual salience and attention switching experimental manipulations.	1) Importance of varying the model position 2) Replication of previous results independently from the manipulation of the secondary task 3) Support for attraction hypothesis and for the involvement of attention in CIB

	Sample	Tasks and Scoring procedure for CIB	Results	Conclusion
		Normal modelling studies		
Chapter 9	Young adults (*n* = 12)	• Complex multipart shapes graphic copying with and without visual feedback (manipulation of manual monitoring) • Quantitative (horizontal and vertical midpoint)	1) Small graphic copying bias toward the model position in vision condition (horizontal midpoint) 2) Small graphic copying bias away from the model position in no-vision condition (horizontal midpoint) 3) Higher bias toward the model in the no-vision condition than in vision (vertical midpoint)	1) Adults can show a drawing bias toward the model as predicted by the attraction hypothesis 2) Importance of varying the model position 3) Role of the manual monitoring needs to be further explored since the inconsistency in the results of the manipulation of vision
Chapter 10	• Young adults (*n* = 16) • Young adults (*n* = 8) • Older adults (*n* = 10)	• no attentional load (series of pointing movements) -attentional load (pointing movements/ letter K naming task) • low (pointing movements/letters naming task) - high attentional load (pointing movements/attentional switching task) • low (pointing movements/letters naming task) - high attentional load (pointing movements/attentional switching task) • Quantitative (mean deviation from the horizontal axis of the pointing movements)	1) Small manual bias toward the location of the letters in the high attentional load versus constant rightward bias in no attentional load 2) Manual bias toward the location of the letters, but no effect of attentional load 3) Pointing movement bias away from the location of the letters in low attentional load and rightward bias in high attentional load.	1) Normal participants can show a manual bias toward the focus of attention/fixation 2) The inconsistency between results should be further explored in relation to the attention and action literature, focusing on the movement toward a target when a distractor is presented.

CONCLUSION

The main achievements of the present thesis have been to fill some methodological and theoretical gaps which emerged from a review of the literature on CIB. First, the methodology used in most of the studies of the present thesis combined qualitative and quantitative approaches to study the phenomenon. Both approaches proved to be useful. The qualitative categorization of CIB into two main CIB classes, near- and overlap-type CIB, was developed in relation to the tasks used, and better-defined distinctions between categories were applied than in the previous literature. For instance, the near-type CIB was arbitrarily defined as any misplacement of the graphic copying within 10 mm distance, from the division line of the specific graphic copying task presented in the MODA (Chapter 3). This operational definition was useful to provide a replicable and precise measure of this CIB type, previously vaguely defined as the tendency to perform the copy very close to the model. On the other hand, quantitative approaches proved to be important tools in the assessment of the distribution of the graphic performance in the working space, being able to detect small drawing biases, which might not have been distinguished with a qualitative scoring procedure. Moreover, it was shown that a straightforward quantitative measure based upon average deviation toward the model can provide more powerful measure of CIB than previously applied quantitative schemes. For instance, the average of the graphic copying vertical distribution was shown to be a more sensitive measure of CIB than the slope of the copy in Luria's task, proposed by Lee et al. (2004) and adopted by other authors (Chin et al., 2005) (see Chapter 6).

Another important methodological accomplishment of the present work was to highlight the importance of varying the model position. Several studies presented here showed that healthy subjects have a default tendency to drift up the page (see, for instance, Chapter 5), confirming the crucial importance of varying the model position in order to establish that a drawing bias is truly model-directed. This manipulation must be applied in particular when CIB is assessed using a laterally extended model, such as Luria's picture (Luria, 1966). This last task has been shown to be an important tool for the assessment of CIB in the present thesis. As an example, this task proved to be a more sensitive measure of CIB than the classical geometrical figure copying task in pre-school children, as a significant effect of the age of the children on CIB was found in Luria's copying task but not in the geometrical figure copying task (see Chapter 6).

From a theoretical point of view, this thesis has radically revised the conventional view and definition of CIB. First, this work demonstrated that CIB is not a manifestation of CA as classically considered. The studies reported showed that although CIB and CA are often observed in conjunction, they have also appeared as different symptoms, and therefore they need to be investigated independently of one another. Moreover, it was confirmed that the appearance of CIB is not confined to constructional tasks, but also appears in other domains, such as gesture imitation. Most importantly, CIB presents not only similar characteristics in these different domains, but common mechanisms may underlie the various task-specific manifestations of CIB. This thesis shows that CIB is a general behaviour, which appears in different cognitive domains, and is not specific to copying tasks. It was demonstrated that CIB is often observed in copying tasks because these types of tasks require paying attention to one location and performing an action in another. Accordingly, it can be equally elicited in non copying tasks with similar requirements.

The most important achievement of this thesis was to show that CIB is a general default behaviour in which manual performance is automatically driven toward the focus of attention and/or fixation. Moreover, the series of studies here presented showed different evidence which converged toward a cognitive origin of this behaviour. It was argued that attentional and/or executive deficits are the primary critical factors in the expression of CIB. It was further demonstrated that although these factors are key causes in the appearance of CIB, they have a different cognitive weight in the different manifestations of CIB. For instance, whereas attentional deficits have been shown to be the unique factors in the appearance of near-type CIB, additional visuo-constructional deficits are likely to be observed in patients with overlap-type CIB (see Chapter 3). This result implies that the different manifestations of CIB do not simply lie on a continuum of severity, but also reflect a differential involvement of attention and visuo-constructional factors.

Beside the achievements of this thesis it is worth mentioning the limitations of this work. This thesis focused on exploring the attraction account of CIB in dementia and childhood, as well as in normal participants, but it did not directly test the compensation hypothesis of CIB in these different populations. The role of this hypothesis and of visuospatial and working memory deficits in the appearence of CIB cannot be definitively excluded. Morever, the results of the present thesis are most related to the near type of CIB and further studies should be conducted to explore the more severe form of CIB, consisting in the tendency to trace the lines of the model. For instance, from the present work it is not possible to exclude that the compensation hypothesis might account for this type of behaviour. Finally, as proposed in Chapter 3, the relative role of these two hypotheses in the apperence of CIB in different patients' populations should be further explored.

FUTURE DIRECTIONS

The present work did not aim to provide a comprehensive explanation of CIB, but instead sought to offer a new perspective on this phenomenon. It seems that CIB is a general default behaviour likely to be elicited in tasks similar in structure and demand to copying tasks. This evidence opens the way to new studies, which may regard the phenomenon in different domains and, perhaps most importantly, focus on its relevance and implications in the patients' daily life, identifying problematic aspects and proposing possible areas of interventions.

For instance, as suggested in Chapter 3, a direct manifestation of this tendency may appear in driving. During this daily activity, patients with AD may show the tendency to veer toward salient visual cues, such as a pedestrian crossing the street, raising the likelihood, for instance, of a collision with the visual cues (Ambron et al., 2009a). Although this hypothesis will need to be tested future studies, some initial evidence in support of this hypothesis can be gleaned from the literature. Mapstone et al. (2009) showed that the pattern of eye movement in patients with AD viewing a dynamic scene which reproduced the driver's perspective while driving was characterized by fewer fixations in the central region of interest (the road). Instead, patients with AD looked more often at stimuli in the peripheral part of the scene. This tendency might have a direct impact on driving performance in AD, specifically on the ability to maintain correct lane positioning, with drivers veering more toward peripheral attention-attracting stimul. This interpretation could account for the high number of crossed lane boundaries observed in patients with AD in a driving simulator experiment (Szlyk et al., 2002). Moreover, if this tendency is secondary to attentional depletion, as this thesis suggests, then it may also be observed in other drivers with reduced attentional capacity, regardless of their diagnosis.

To conclude, the present thesis opens the way to looking at a peculiar phenomenon, which has been poorly investigated in the past, possibly because it has been considered of little relevance and impact in patients' daily life. On the contrary, the present work suggests that CIB might have strong ecological validity and the study of the impact of this symptom in the patients' daily life might be relevant not only to cognitive theory, but to the safety and well-being of patients, caregivers, and the overall society.

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Appendices

APPENDICES CHAPER 3

a) Protocol of the MODA with English translation.

TEST DI ORIENTAMENTO TEMPORALE ***(Temporal Orientation test)***	RISPOSTA DEL SOGGETTO (Subject's answer)	RISPOSTA CORRETTA (Correct answer)	PUNTEGGIO (Score)
1) Mi dica in che giorno del mese siamo (What is the date?)			
2) Mi dica in che mese dell'anno siamo (What is the month?)			
3) Mi dica in che anno siamo (What is the year?)			
4) Mi dica che giorno della settimana e' oggi (What is the day of the week?)i			
5) Mi dica che ore sono (What time is it?)			
Punteggio totale (Total score)....../10			

TEST DI ORIENTAMENTO SPAZIALE ***(Spatial Orientation test)***	RISPOSTA DEL SOGGETTO (Subject's answer)	RISPOSTA CORRETTA (Correct answer)	PUNTEGGIO (Score)
1) Mi dica in che citta' siamo (In which city are we?)			
2) Mi dica dove siamo ora (Where are we now?)			
3) Mi dica in che nazione siamo (in which country?)			
Punteggio totale (Total score)....../3			

TEST DI ORIENTAMENTO PERSONALE ***(Personal Orientation test)***			
	RISPOSTA DEL SOGGETTO (Subject's answer)	RISPOSTA CORRETTA (Correct answer)	PUNTEGGIO (Score)
1) Come si chiama? (What is your name?)			
2) Quanti anni ha? (How old are you?)			
3) Ricorda la sua data di nascita? (What is your date of birth?)			
4) In che citta' e' nato? (In which city were you born?)			
5) Qual'e' il suo indirizzo attuale? (What is your current address?)			
6) Quanti anni di scuola ha frequentato? (Fo how may years have you been at school?)			
7) Mi ha mai visto o conosciuto in passato? (have you ever seen or meet me before?)			
Punteggio totale (Total score)....../10			

TEST DI ORIENTAMENTO FAMILIARE ***(Family Orientation test)***

	RISPOSTA DEL SOGGETTO (Subject's answer)	RISPOSTA CORRETTA (Correct answer)	PUNTEGGIO (Score)
1. *Padre (Father)*			
Mi dica come si chiama suo padre (What's your father's name?)			
E' ancora vivente? (Is he still alive?)			
Quanti anni ha/o aveva quando e' morto? (how old is he/was he when he died?)			
2. *Madre (Mother)*			
Mi dica come si chiama sua madre (What's your mother's name?)			
E' ancora vivente? (Is she still alive?)			
Quanti anni ha/o aveva quando e' morta? (how old is she/was she when she died?)			
3.*Coniugi (Spouse)*			
Mi dica come si chiama sua moglie/marito (What's your wife/husband's name?)			
E' ancora vivente? (Is she/he still alive?)			
Quanti anni ha/o aveva quando e' morta/o? (how old is she/he - was she/he when she/he died?)			
4°. Fratelli- o in alternative figli (Brothers/sisters – or use children as an alternative)			
Lei ha fratelli o sorelle? (Have you got brothers or sisters?)			
Se si, di ognuno di essi mi dica il nome (If so, please tell me the name of all of them)			
Se sono ancora viventi, quanti anni hanno o a quanti anni sono morti? (If they are still alive, how old are they now or at what age did they died?)			

Punteggio totale (Total score)....../12

SCALA DI AUTONOMIA ***(Authonomy scale)*** Le domande vanno rivolte a un congiunto o a un convivente (indicare chi). *The questions should be asked to the carer*	
Deambulazione- *Walking*	0= non valutabile – *not applicable* 1= non e' in grado di camminare – *he/she cannot walk* 2= cammina solo se aiutato – *he/she can walk only with the help of someone* 3= e' autonomo – *he/she is independent*
Capacita' di vestirsi- *Dressing ability*	0= non valutabile – *not applicable* 1= non e' in grado di vestirsi e/o non collabora quando aiutato – *he/she is not able to dress his/herself and he/she does not collaborate when someone is helping him/her* 2= non e' in grado di vestirsi, ma collabora quando aiutato – *he/she is not able to dress his/herself, but he/she does collaborate when someone is helping him/her* 3= e' autonomo – *he/she is independent*
Igene personale- *Personal hygiene*	0= non valutabile – *not applicable* 1= non e' in grado di provvedere all'igene personale – *he/she is not independent* 2=collabora a mantere una buona igene personale – *he/she collaborate to keep a good personal hygeine* 3= e' autonomo – *he/she is independent*
Incontinenza- *Incontinence*	0= non valutabile – *not applicable* 1= e' incontinete – *he/she isincontinent* 2=avverte lo stimolo, ma non controlla gli sfinteri – *he/she feel the need, but does not have control of his/her sphincters* 3= e' autonomo – *he/she is independent*
Alimentazione- *Incontinence*	0= non valutabile – *not applicable* 1= e' incontinete – *he/she isincontinent* 2=avverte lo stimolo, ma non controlla gli sfinteri – *he/she feel the need, but does not have control of his/her sphincters* 3= e' autonomo – *he/she is independent*

APPRENDIMENTO REVERSAL *(Reversal Learning)*			
STIMOLO *(stimulus)*	ESATTO (Correct)	NON REVERSAL	ALTRO (other)
1. Palmo- *palm*			
2. Palmo - *palm*			
3. Pugno – *fist*			
4. Pugno – *fist*			
5. Palmo - *palm*			
Punteggio totale (Total score)....../5			

TEST ATTENZIONALE *(Attentional test)*				
RIGA *(stimulus)*	RISPOSTA (Correct)		FALSI ALLARMI	OMISSIONI (other)
I)				
II)		(0)		
III)		(1)		
IV)		(2)		
V)		(1)		
VI)		(0)		
VII)		(1)		
VIII)		(0)		
IX)		(2)		
X)		(2)		
XI)		(1)		
Punteggio totale in 45 sec (Total score in 45 sec)....../10				
Tempo impiegato per completare l'intera matrice (Overall time used to complete the matrix)				

	5
(A)	2 6 5 9 4 5 2 5 2 6
(B)	4 1 2 5 1 3 0 4 9 1
(I)	0 6 7 6 8 9 8 0 8 0
(II)	9 0 4 3 0 1 9 3 7 6
(III)	7 9 5 3 7 8 8 9 7 6
(IV)	7 3 7 6 8 5 8 5 3 2
(V)	5 2 3 1 2 3 1 7 2 8
(VI)	4 1 7 4 7 6 9 1 8 3
(VII)	2 7 4 2 6 2 9 4 5 0
(VIII)	4 3 4 0 4 3 0 2 8 2
(IX)	6 1 5 6 1 5 8 3 6 9
(X)	4 5 2 8 1 3 9 1 5 1
(XI)	7 9 7 5 0 7 3 4 0 8

INTELLIGENZA VERBALE *(Verbal intelligence)*
1). Che differenza c'e tra un camion e una corriera? (*what is the difference between a lorry and a coach?*)………………………………………………………………………………………………/3 2) Ora le leggero' un proverbio molto commune. Lei dovera' spiegare il suo significato: "Una rondine non fa primavera". (*Now I will read a common proverb and I will ask you to exaplan its meaning. "a swallow doesn't make spring"*………………………………………………………………………………/3 Punteggio totale (Total score)....../6

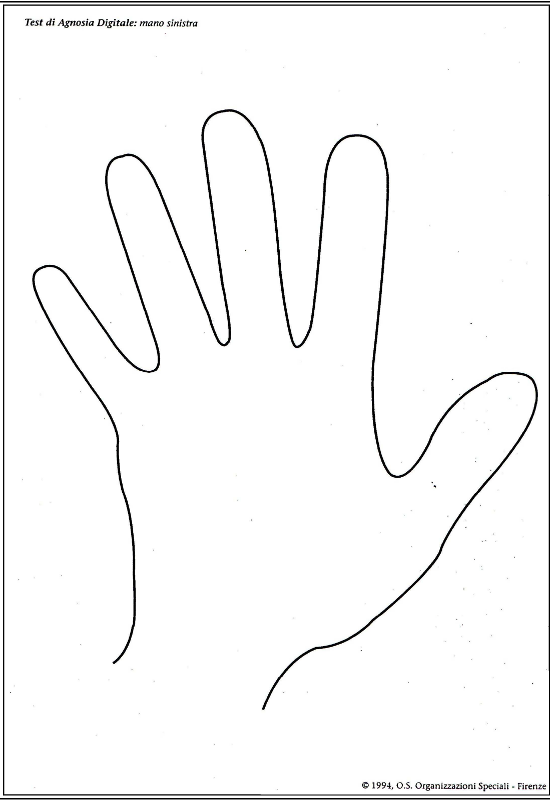
RACCONTINO *(Short story)*
Sei dicembre, la scorsa settimana un fiume straripo' in una piccola citta' situata a venti chilometri da Torino, L'acqua invase le strade e le case. Quattordici persone annegarono e seicento si ammalarono a causa dell'umidita' e del freddo, Nel tentativo di salvare un uomo un ragazzo si feri' le mani *Sixth of December, last week a river overflowed in a small city at twenty kilometres from Tourin. The water flooded the streets and the houses. Fourteen people drowned and sixhoundreds became ill for the humidity and for the cold. Attempting to save a man, a boy hurted his hands.* RIPETIZIONE *(repetion)*………………………………………………………………………………… Punteggio totale per eventi (Total score for events)....../8

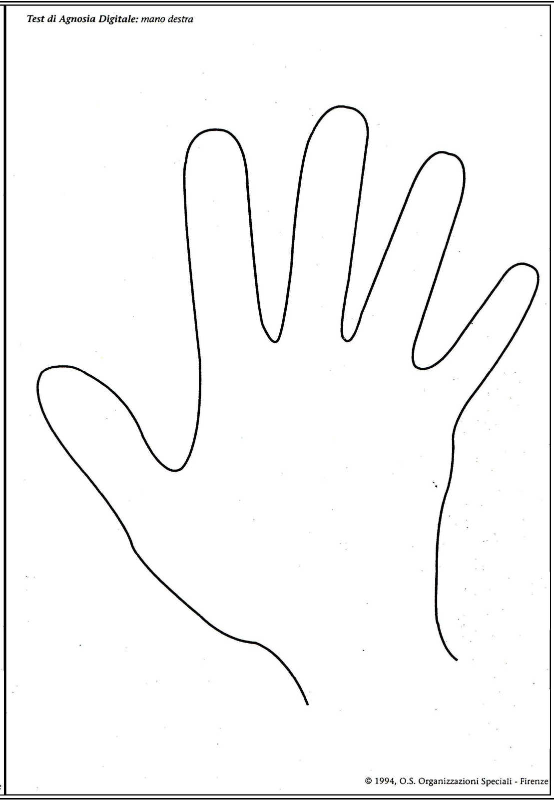
TEST DI PRODUZIONE DI PAROLE *(Reproduction Of Words Test-)*
Animali *(animals)*: cane, gatto, *(cat, dog)*………………………………………………………………………… Punteggio (Score)....../5 (0= 0-4 parole/words; 1= 5 to 7 parole/words; 2=8–11 parole/words; 3=12 – 15 parole/words; 4= 16 to 17 parole/words; 5= piu' di 17 parole/more than 17 words)

TEST DEI GETTONI *(Token test)*	
Tocchi il cerchio verde -*Touch the green circle*	---
Tocchi il quadrato bianco - *Touch the white square*	---
Tocchi il quadrato bianco e il cerchio verde - *Touch the white square and the green circle*	---
Tocchi il cerchio bianco e il cerchio rosso - *Touch the white circle and the red circle*	---
Metta il cerchio rosso sopra il quadrato verde - *Place the red circle on the top of the green square*	---
Punteggio (Score)....../5	

AGNOSIA DIGITALE ***(Digit Agnosia)*** - da eseguire sulla mano dominate/*to be executed with the dominant hand*

PROVA PRELIMINARE *Training phase*	RISPOSTA *Answer*	TEST	RISPOSTA *Answer*
1.Medio/Middle finger		1. Pollice-medio / Thumb-middle finger	
2. Mignolo/Little finger		2. Medio-Anulare / Middle finger-ring finger	
3. Indice /Index finger		3. Medio-Indice / Middle finger-forefinger	
4. Pollice/Thumb		4. Mignolo-Pollice / Little finger-Thumb	
5. Anulare/Ring finger		5. Indice-Anulare / Forefinger-ring finger	
		Punteggio (Score)....../5	



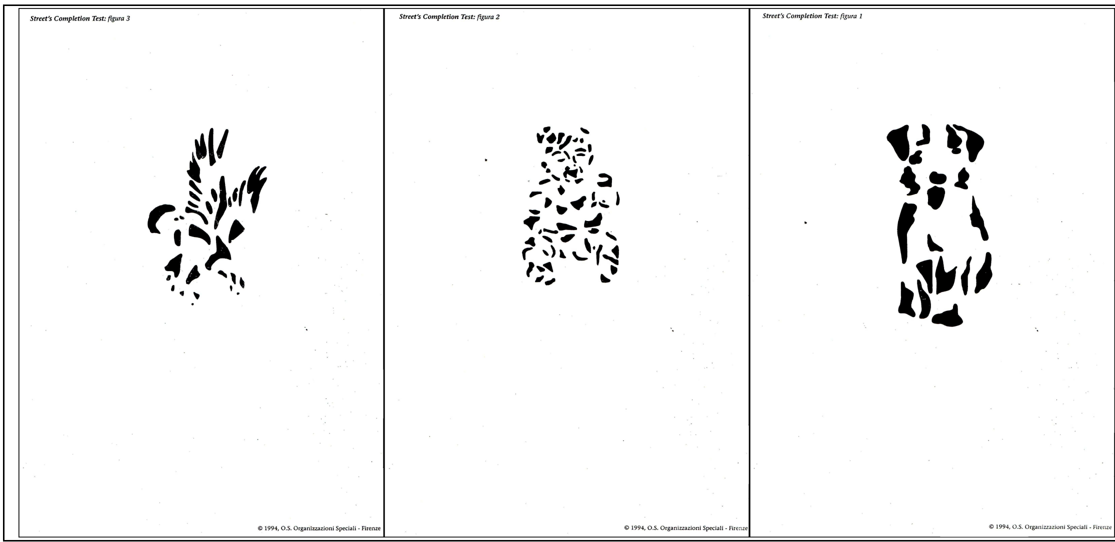


APRASSIA COSTRUTTIVA *(Constructional apraxia)*

STIMOLO (stimulus)	PUNTEGGIO *(Score)*
1. Quadrato/Square	--
2. Rombo/Rhombus	--
3. Greca/ Multipart Picture	--
Punteggio (Score)....../3	

STREET'S COMPLETION TEST

STIMOLO (stimulus)	RISPOSTA *(answer)*
1. cane/dog	--
2. bebe'/baby	--
3. Uccello/ bird	--
Punteggio (Score)....../3	



b) Median performance of AD patients and test of normality (Kolmogorov-Smirnov) for the different MODA subtest

	Median (range)	*Statistic (D)*	*p*
Behavioural scales	76 (9-89)	.105	.001
Verbal Intelligence	50 (0-100)	.225	.001
Digit Cancellation	70 (0-100)	.171	.001
Verbal Fluency	20 (0-100)	.176	.001
Luria's Reversal Learning	80 (0-100)	.236	.001
Prose Memory	0 (0-78)	.459	.001
Finger Identification	60 (0-100)	.162	.001
Token	90 (0-100)	.209	.001
Street's Completion	67 (0-100)	.251	.001
Figure copying	1 (0-2)	.152	.001

c) Spearman Rho's correlation for AD

	Verbal Intelligence	*Digit Cancellation*	*Verbal Fluency*	*Luria's Reversal Learning*	*Prose Memory*	*Finger Identification*	*Token*	*Street's Completion*	*Figure copying*
Behavioural scales	.397*	.434*	.525*	.394*	.196*	.426*	.389*	.406*	.372*
Verbal Intelligence		.305*	.419*	.346*	.242*	.345*	.391*	.258*	.237*
Digit Cancellation			.305*	.335*	.196*	.440*	.380*	.382*	.516*
Verbal Fluency				.376*	.221*	.361*	.412*	.289*	.287*
Luria's Reversal Learning					.140*	.346*	.354*	.218*	.318*
Prose Memory						.163*	.209*	.125*	.125*
Finger Identification							.459*	.371*	.419*
Token								.332*	.395*
Street's Completion									.359*

*$p < .001$

d) Step summary report of the variables not in the equation in the Multinomial logistic regression

			-2 Log Likehood	χ^2	*p*
0	Enter all		1443.6		
1	Removed	*Prose Memory*	1443.7	0.039	.98
2	Removed	*Token*	1443.7	0.054	.97
3	Removed	*Verbal Fluency*	1444.2	0.492	.78
4	Removed	*Verbal Intelligence*	1445.1	0.884	.64
5	Removed	*Finger Identification*	1445.9	0.838	.65
6	Removed	*Behavioural scales*	1447.8	1.870	.39
7	Removed	*Street's Completion*	1451.9	4.152	.12
8	Removed	*Reversal Learning*	1456.5	4.598	.10

e) Performances (in percentages) in each MODA subtest in the first and second assessment.

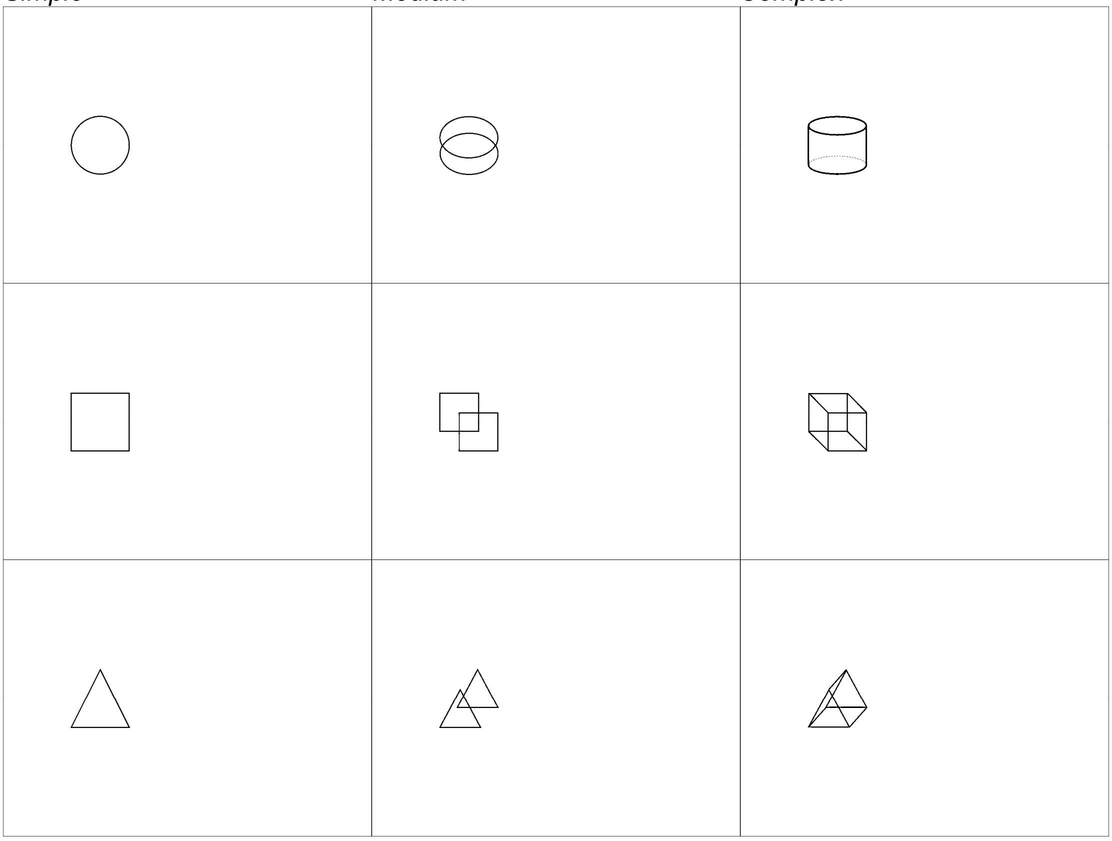
		First session	**Second session**	*z*
Behavioural scales	Median Range	91 63-100	76 40-100	-9.49***
Verbal Intelligence	Median Range	50 0-100	50 0-100	-4.83***
Digit Cancellation	Median Range	80 0-100 60-100	70 0-100 40-90	-5.91***
Verbal Fluency	Median Range	40 0-100	20 0-100	-4.83***
Luria's Reversal Learning	Median Range	100 0-100	60 0-100	-4.70***
Prose Memory	Median Range	0 0-76	0 0-82	-2.17*
Finger Identification	Median Range	60 0-100	40 0-100	-5.37***
Token	Median Range	90 20-100	80 0-100	-5.42***
Street's Completion	Median Range	67 0-100	67 0-100	-4.21***
Figure copying	Median Range	1 0-2	1 0-2	-3.35**

* $p < .05$; ** $p < .005$; $p < .001$

APPENDICES CHAPTER 6

a) Nine geometrical pictures copying task

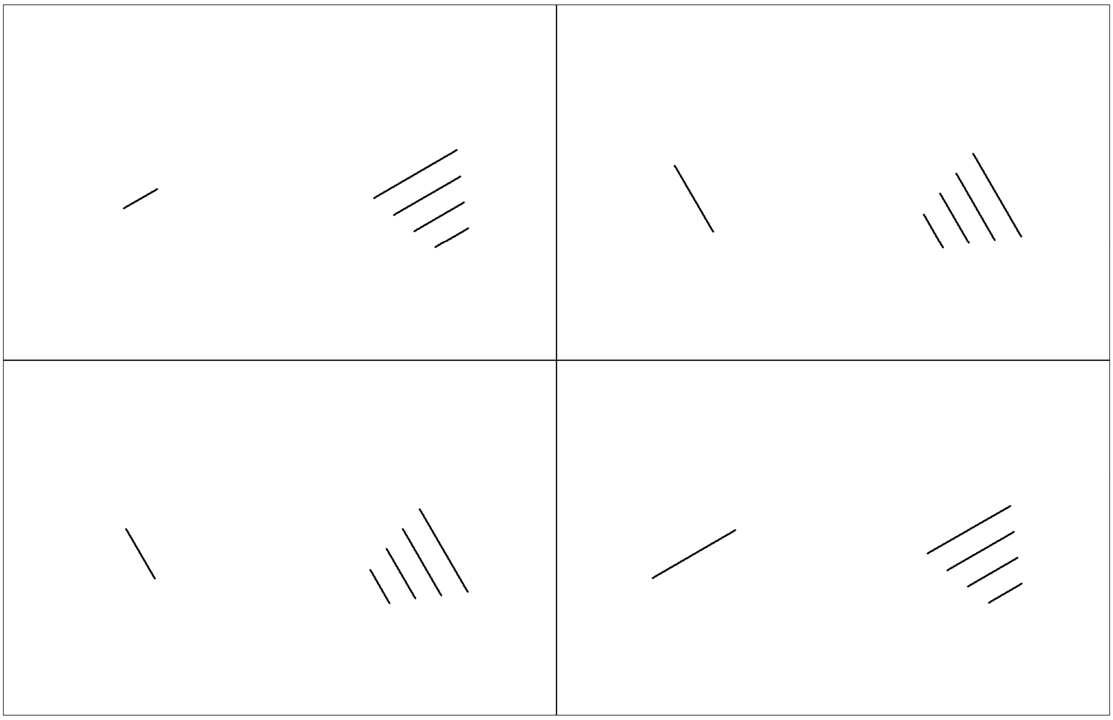
Simple *Medium* *Complex*



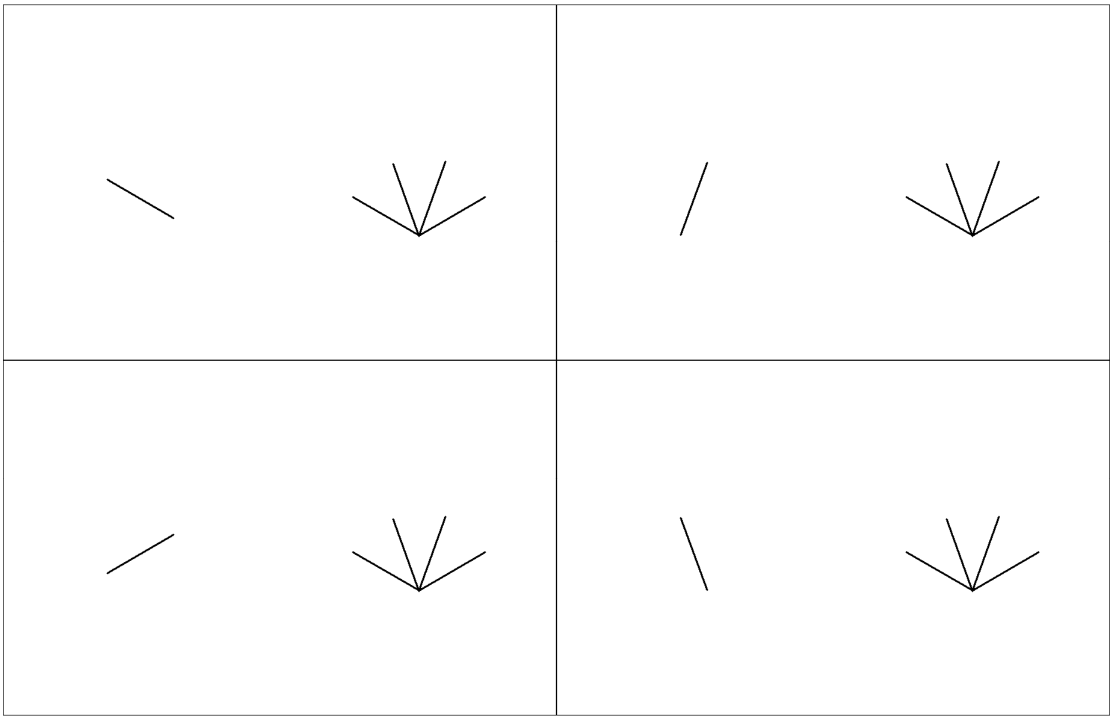
b) Visuospatial tasks

Visuoperceptual tasks

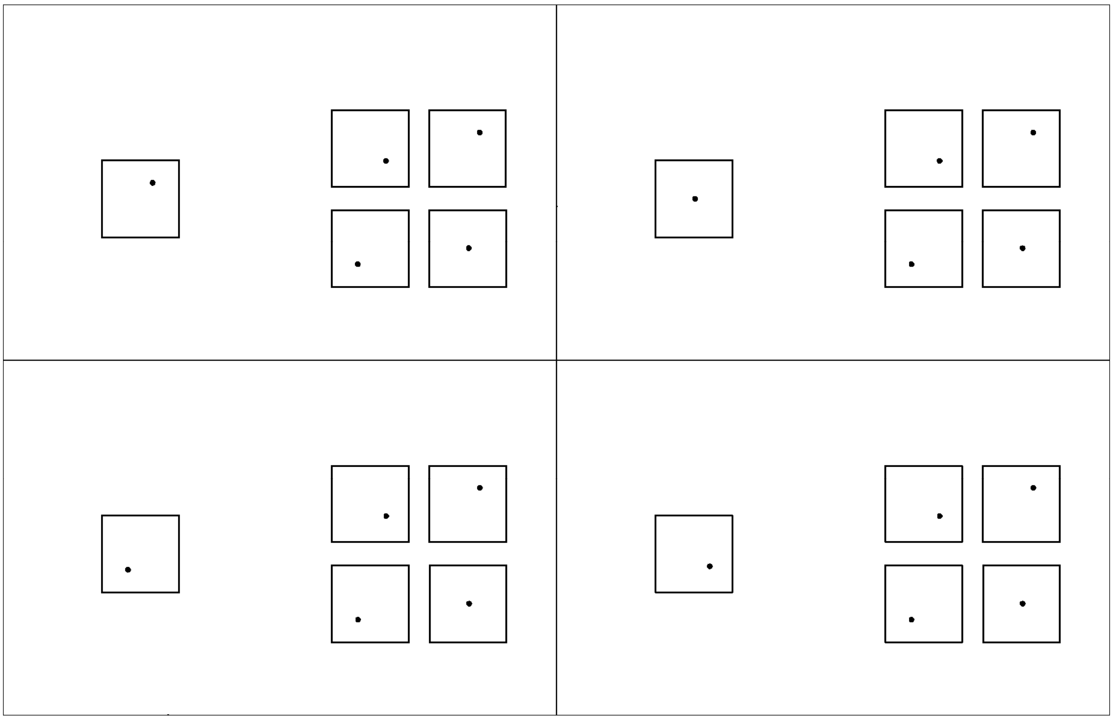
Length of lines



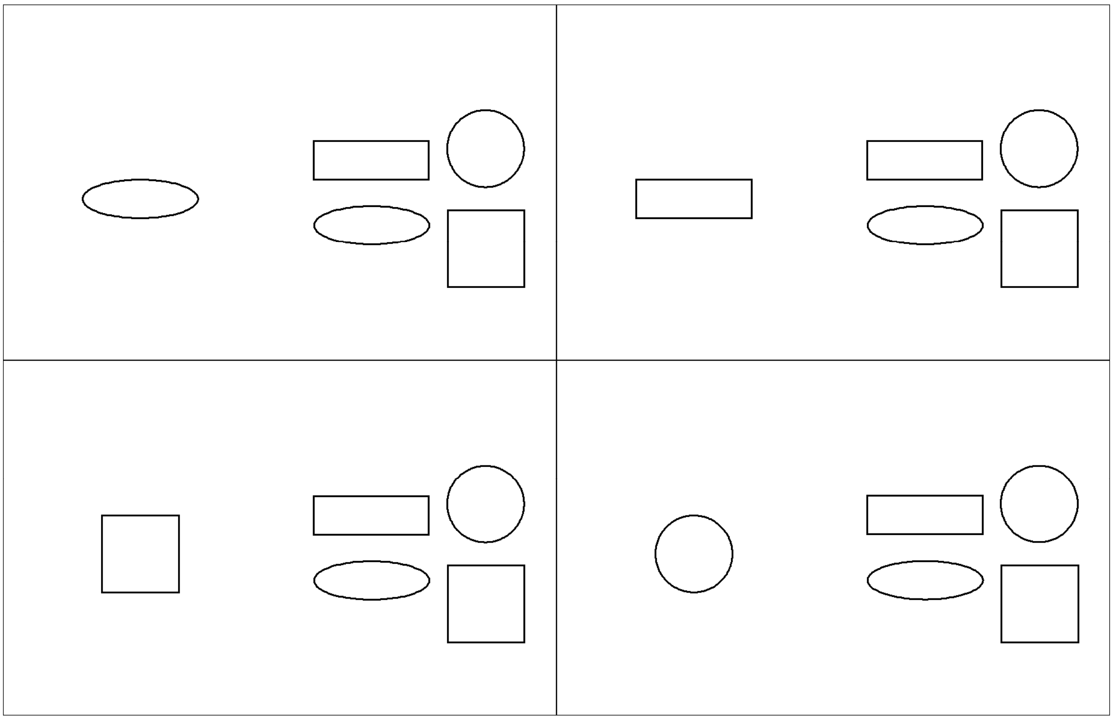
Orientation of lines



Position of points

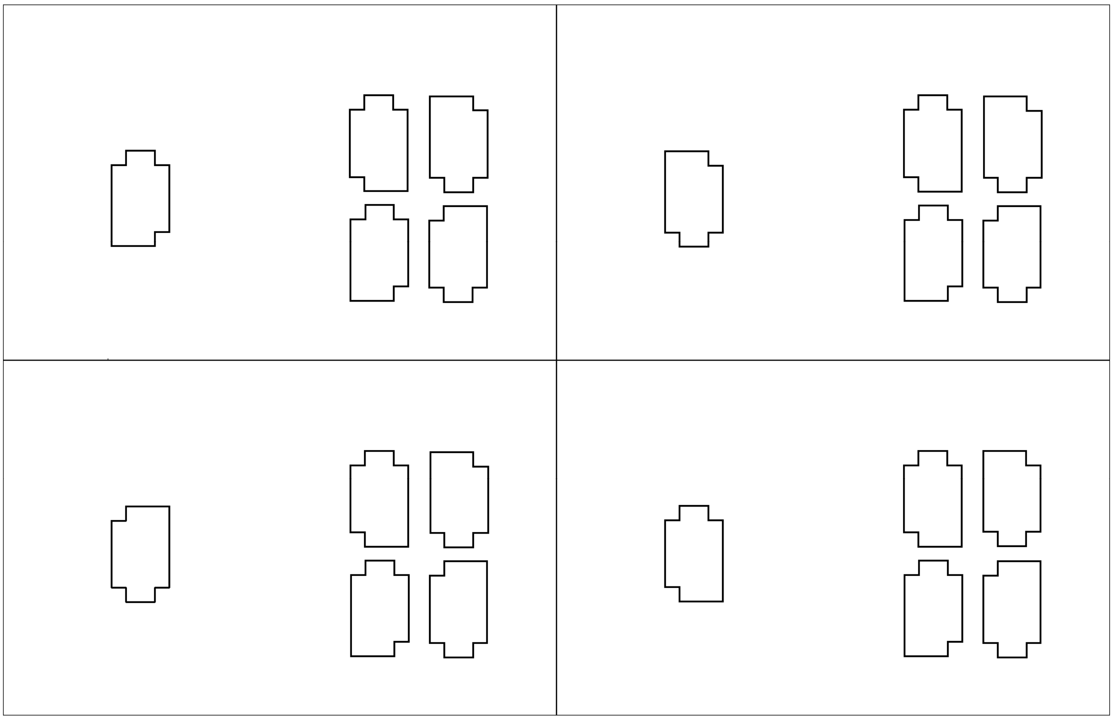


Geometrical shapes

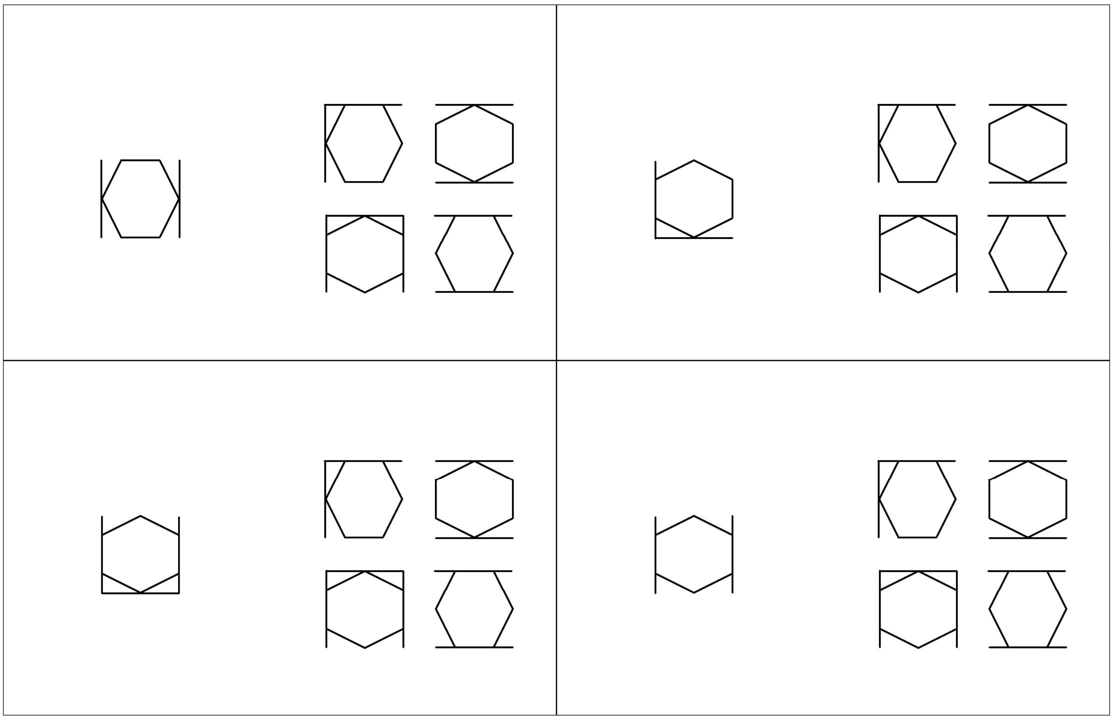


Mental Representation tasks

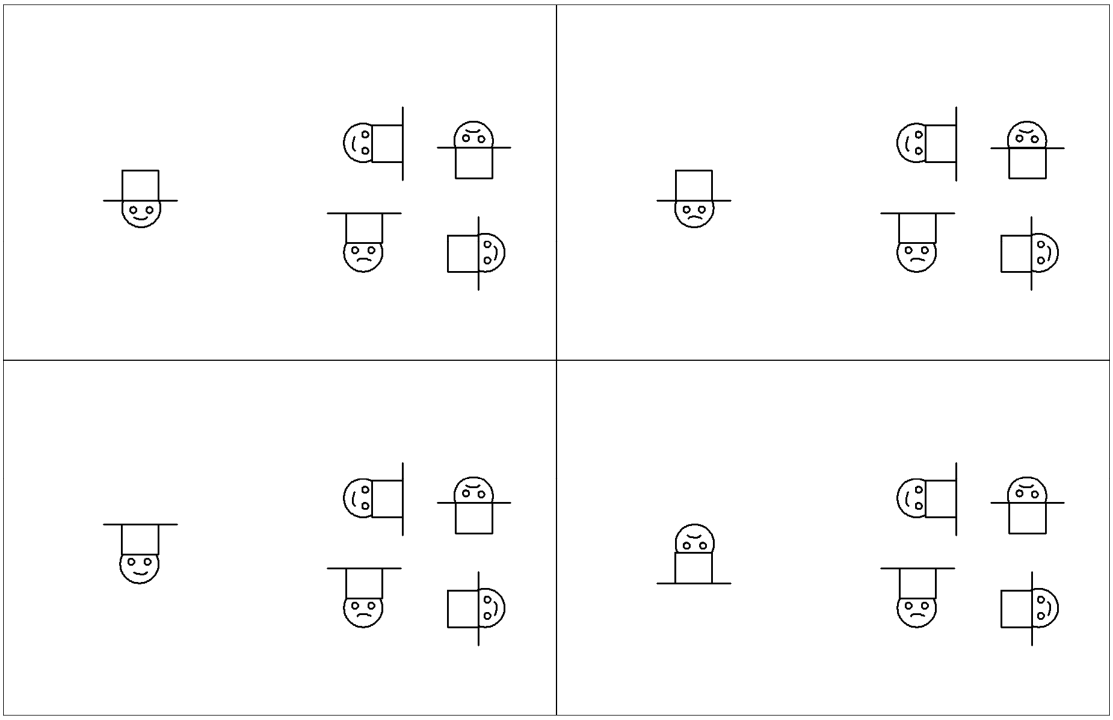
No sense geometrical shapes



Hidden geometrical pictures



Mental rotation of faces



c) Attention

Sustained Attention task

Rooster
Dog
White screen (4500 ms)
Cow
Dog
Rooster
White screen (3500 ms)
Rooster
White screen (1500 ms)
Cow
White screen (5500 ms)
Cat
Cow
White screen (7500 ms)
Cat
White screen (6500 ms)
Dog
Cat
White screen (2500 ms)

Attention switching task

Cow
Rooster
Cat's face
Cow's face
Cat's face
Dog
Dog's face
Cat
Rooster's face
Rooster
Cow
Dog
Dog's face
Rooster's face
Cat
Cow's face

d) Median performance of the children and test of normality (Kolmogorov-Smirnov) for the different tasks.

	Median (range)	*Statistic (D)*	*p*
Visuo-perceptual	75 (44-94)	.158	$p < .05$
Mental representation	42(8-92)	.145	$p < .05$
Visuospatial	**59 (32-86)**	**.117**	**n.s.**
Digit Span	21 (0-43)	.161	$p < .01$
Corsi Span	33 (0-44)	.193	$p < .001$
Working memory	**29 (0-44)**	**.158**	$\boldsymbol{p < .05}$
Selective attention	58 (6-96)	.109	n.s.
Sustained attention	92 (25-100)	.235	$p < .001$
Attention switching	69 (12-100)	.216	$p < .001$
Attention	**71 (17-96)**	**.140**	$\boldsymbol{p < .05}$

e) Median and range performances in all the subtests for male and female, and Z coefficient (Mann-Whitney) for comparison of the performance in the different tasks between male and female groups.

		Male	**Female**	***z / p***
Visuo-perceptual	Median Range	69 44-94	75 50-88	-0.10 (n.s.)
Mental representation	Median Range	42 17-75	50 8-92	-0.91 (n.s.)
Visuospatial	Median Range	58 37.5-80	60 32-86	-0.74 (n.s.)
Digit Span	Median Range	21 0-43	21 0-43	-0.20 (n.s.)
Corsi Block test	Median Range	33 0-44	28 0-44	-0.51 (n.s.)
Working memory	Median Range	33 0-40	27 0-44	-0.58 (n.s.)
Selective attention	Median Range	65 6-96	54 8-92	-1.13 (n.s.)
Sustained attention	Median Range	92 33-100	100 25-100	-1.58 (n.s.)
Attention switching	Median Range	62.50 12.5-100	75 25-100	-0.48 (n.s.)
Attention	Median Range	77 17-96	67 26-94	-0.22 (n.s.)

f) *Z* coefficient (Mann-Whitney post hoc test) for comparison of the performance in the different tasks between age groups of children.

	Group 1 Vs. Group 2	**Group 2 Vs. Group 3**	**Group 1 Vs. Group 3**
Mental representation	-2.47*	-1.14	-3.21**
Visuospatial	-2.48*	-1.33	-3.32**
Digit Span	-2.44*	-0.52	-2.44*
Corsi Block test	-1.62	-2.41*	-3.65***
Working memory	-2.39*	-0.95	-3.46**
Selective attention	-4.09***	-0.51	-4.22***
Sustained attention	-1.76	-1.33	-2.93**
Attention switching	-2.03*	-0.22	-2.44*
Attention	-3.83***	-0.92	-4.36***

*$p < .05$; **$p < .005$; ***$p < .001$

g) Spearman rho’s correlation.

In this table: VS is visuo-perceptual task, MR is mental representation task, DS is the digit span, Co is the Corsi block test and SeA, SuA and AS are respectively selective, sustained and attentional switching tasks.

	Months	*VP*	*MR*	*CS*	***VS***	*DS*	*CO*	***WM***	*SeA*	*SuA*	*AS*	***AT***
CIB	.524****	.172	.366*	.284	**.369***	.277	.505***	**.448*****	.525****	.330*	.537****	**.662******
Months		.433**	.584****	.551****	**.634******	.440***	.618****	**.616******	.689****	.525****	.343*	**.712******
VP			.303	.266	**.734******	.335*	.209	**.357***	.279	.275	.197	**.343***
MR				.366*	**..833******	.397*	.448***	**.508*****	.409**	.414**	.467***	**.594******
CS					.414**	.281	.324*	**.327***	.528****	.459***	.122	**.476*****
VS						.401**	.370*	**.474*****	.418**	.413**	.400*	**.563******
DS							.404**	**.811******	.570****	.327*	.242	**.538******
CO								**.826******	.481***	.506***	.540****	**.689******
WM									.586****	.503***	.488***	**.717******
SeA										.264	.242	**.715******
SuA											.408**	**.617******
AS												**.774******

* $p < .05$; ** $p < .01$; *** $p < .005$;**** $p < .001$